MASTER PLAN APPENDIX A PROJECT DESCRIPTIONS

Intelligent Vehicle-Highway Systems

Denver Metro Area

Project IVH-MP 9108(1)

for the
COLORADO DEPARTMENT OF TRANSPORTATION

C-STAR

February 1994

by:
CENTENNIAL ENGINEERING, INC.
CASTLE ROCK CONSULTANTS
BALLOFFET AND ASSOCIATES, INC.

IVHS Study for the Denver Metro Area

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LIST OF ACRONYMS/ABBREVIATIONS

AHS	Automated Highway System
APTS	Advanced Public Transportation Systems
ATIS	Advanced Traveler Information Systems
ATMS	Advanced Traffic Management Systems
AVCS	Advanced Vehicle Control Systems
AVI	Automatic Vehicle Identification
AVL	Automatic Vehicle Location
CAD	Computer Aided Dispatch
CCTV	Closed Circuit Television
CDOT	Colorado Department of Transportation
CIMC	Colorado Incident Management Coalition
CSP	Colorado State Patrol
CTI	Colorado Transportation Institute
CVO	Commercial Vehicle Operations
DAB	Digital Audio Broadcasting
DPS	Department of Public Safety
DRCOG	Denver Regional Council of Governments
EIS	Emergency Information System
EON	Enhanced Other Networks
FDM	Frequency Division Multiplexing
FHWA	Federal Highway Administration
FM	Frequency Modulation
FMCS	Fleet Management and Control Systems
FSK	Frequency Shift Keying
FTA	Federal Transit Administration
FTE	Full Time Employee
GPS	Global Positioning System
HAR	Highway Advisory Radio
HOV	High Occupancy Vehicle
ISTEA	Intennodal Surface Transportation Efficiency Act of 1991
IVSAWS	In Vehicle Safety and Warning Systems
IVHS	Intelligent Vehicle Highway Systems
MIS	Management Information System
OS1	Open Systems Interconnection
POSIX	Portable Operating Systems Interface
RDS	Radio Data System
RTD	Regional Transportation District
SONET	Synchronous Optical Network
TDM	Time Division Multiplexing
TIC	Traffic Information Center
TMC	Traffic Message Channel
TOC	Traffic Operations Center
TP/TA	Traffic Program/Traffic Announcement
VMS	Variable Message Signs

Objective #l
Provide a Focal Point for Denver's IVHS Activities

Activities

Traffic Operations Center (TOC)

TOC Expert Systems

TRAFFIC OPERATIONS CENTER

Objective

This activity involves the conceptual design, construction and implementation of a Traffic Operations Center (TOC) for the Denver area.

Establishing a TOC is central to the success of IVHS in the Denver area. Its importance will continue beyond the short-term phase and well into the future when the TOC expands its role in supporting and managing available and emerging IVHS technologies over these time periods. A conceptual layout of the TOC is shown in Figure A-l.

The TOC will be a multi-jurisdictional, multi-agency facility. Space will be provided for Colorado Department of Transportation (CDOT) and Colorado State Patrol (CSP) personnel, as well as for public/private sector staff including traffic engineers from cities and counties in the Denver area, the media, traffic information services, enforcement and fire agencies and emergency medical response organizations. CDOT and CSP will integrate staff positions for dispatch and call-taking functions, to take advantage of the cost efficiencies inherent in a pooled, multifunctional employee base. The TOC will be an important platform from which to improve dialogue and cooperation between Denver area jurisdictions. It will also provide opportunities to establish educational and research programs as well as partnerships with the private sector. The board multi-jurisdictional base of the Denver area TOC, along with the range of functions provided, will combine to form an operations center unmatched in North America.

The TOC will serve multiple purposes. These include the following:

- The TOC will be a focal point for multi-agency and public/private sector traffic management efforts. Operators will be able to monitor and manage traffic flows on area freeways and ultimately influence traffic flows on the arterial street network.

  The TOC will serve as a foundation for short, medium and long term IVHS activities in the Denver area. These include Advanced Traveler Information Systems (ATIS), Advanced Public Transportation Systems (API'S), Fleet Management Control Systems (FMCS), Advanced Vehicle Control Systems (AVCS), Advanced Traffic Management Systems (ATMS), demand management systems and the data collection and information dissemination functions associated with these systems.

- The TOC will be a regional incident detection and response center. Coordination of local incident management initiatives will take place under one roof. TOC capabilities will include automated and manual detection of incidents, initiation of response plans including transmission of advisory messages to the appropriate agencies, and the provision of "war room" capabilities for major emergencies which impact traffic and require coordination between multiple agencies, as well as accurate, timely press information. The TOC will also be the coordination center for a cellular call-in system to report accidents and other road problems, and the Denver area courtesy patrol program.

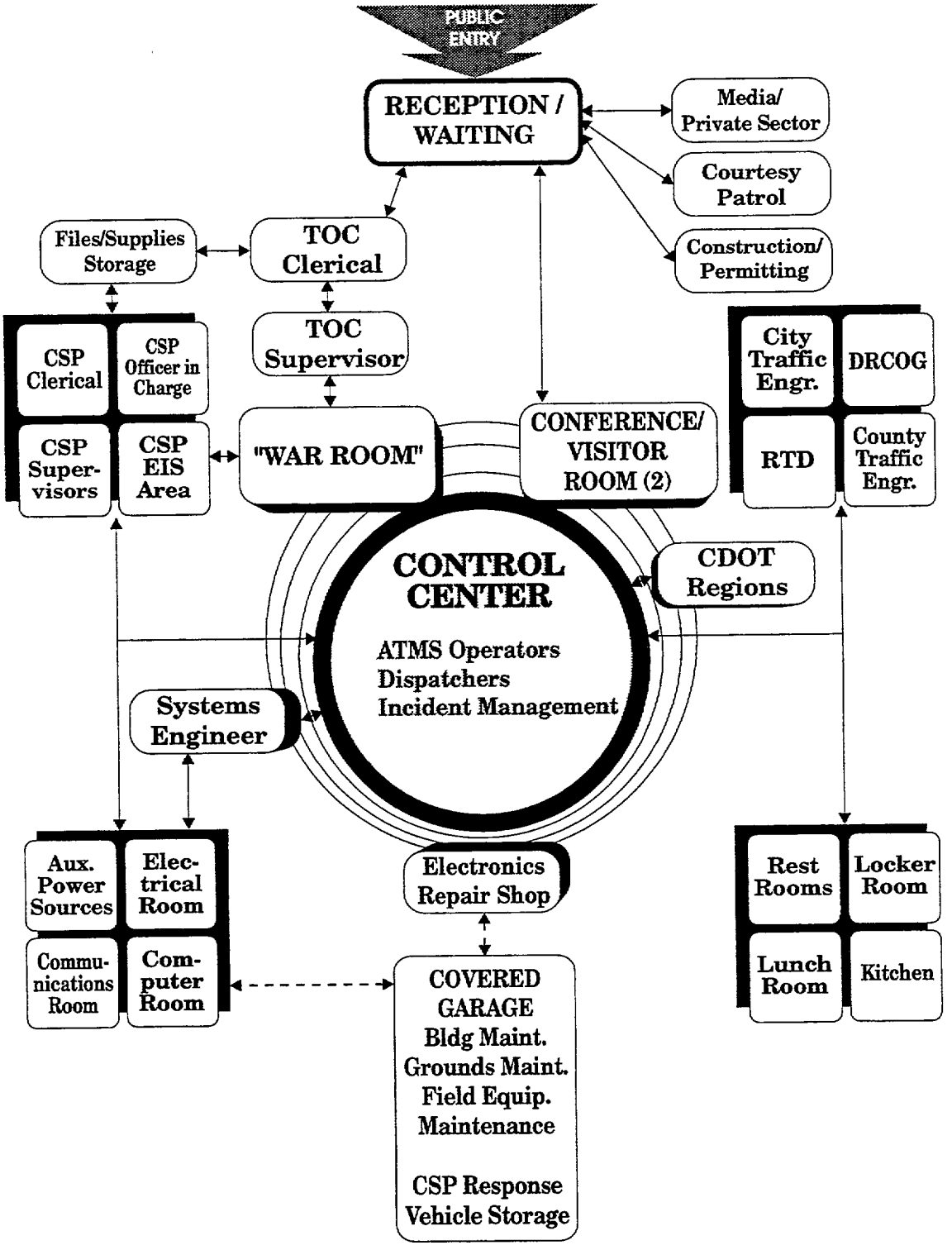


Figure A1 TOC Conceptual Layout

- The TOC will be a dispatch center for CSP enforcement personnel and CDOT Region 1 and 6 maintenance forces. Communication links to other public safety agencies and jurisdictions will enhance the regional aspect of the TOC and improve incident response capabilities. Construction permitting and traffic control planning activities for construction will also be housed within the TOC.

- The TOC will communicate with travelers at home, in-vehicle, and from remote locations such as office building lobbies or shopping centers. Information to be available will include current conditions, weather updates, advance notice of congested areas or construction zones, potential routing options and transit schedules and status. The TOC will generate traffic messages for telephone hotlines, HAR, variable message signs (VMS), and other communications media as well as maintain the appropriate data bases for traveler enquiry services.

- The TOC will provide a location for high technology research in cooperation with local colleges and universities, the Colorado Transportation Institute (CTI), FHWA or other agencies interested in transportation research.

- The TOC will function as the source for a public awareness and education program to inform travelers about the purposes, benefits and activities of the TOC and IVHS in general.

Priority

The implementation of a TOC is central to many potential IVHS activities in the area. The TOC will provide a focal point for these activities in traffic and incident management, thereby supporting the operation of an integrated transportation information system. In addition, the TOC has the potential to be an important platform on which to improve dialogue and cooperation between various Denver metro area jurisdictions.

The establishment of the TOC is consistent with the recommendations of the C-Star plan (Colorado's statewide IVHS initiative) as well as the Colorado Incident Management Coalition (CIMC). In addition, this activity builds directly upon the goals of the IVHS Strategic Plan and Early Action Plan. Its importance will continue from the short-term phase well into the long-term, continuously expanding its role in supporting and controlling available and emerging IVHS technologies.

Applicable IVHS Goals

This activity will primarily address the Denver area IVHS goals which follow:

- Reduce congestion/improve mobility.
- Increase transportation safety.
- Minimize effects of incidents.
- Integrate existing operations and IVHS activities.

- Provide real-time travel information.
- Demonstrate interagency cooperation.
- Provide opportunities for academic research and private sector participation.
- Develop fast-track IVHS implementation.
- Provide operational improvements through technology.

Activity Interrelationships

As outlined previously, establishment of a TOC is central to many elements of IVHS in the Denver area. Without this facility, a major proportion of IVHS activities would be either impractical or severely reduced in scope. In essence, therefore, the TOC is a prerequisite for the overall success and feasibility of IVHS in the metro area.

Because of the time necessary to design and build a permanent TOC, an interim facility is planned to be operational by early 1994. In fact, 12 new full-time employee positions (effective July 1, 1993) have been approved by Colorado's Transportation Commission to fulfill various interim TOC positions. The interim TOC will incorporate the early action recommended activities of the CIMC with initial IVHS activities, as well as existing systems such as ramp metering.

Approach

Initial planning for the Denver metro area TOC is currently underway. CDOT and CSP are the lead agencies responsible for managing this effort. Support and guidance within this effort is being provided by FHWA.

Within the baseline Denver area IVHS study, CDOT has substantially completed concept-level planning for the TOC. In addition, CDOT has a consultant team on board for the TOC's detailed design and planning efforts. The majority of the construction and implementation work will also be performed by private companies under contract to CDOT. However, some tasks will be undertaken by CDOT personnel.

Scope of Work (SOW)

Because of the central role of the TOC, all tasks and associated activities concerning the design, construction and implementation of the facility need to be closely coordinated, particularly with CDOT and CSP. Conceptual planning and detailed design for the TOC are already substantially completed. Work undertaken in this effort includes the following tasks:

- Review state-of-the-art facilities and assess lessons learned.
- Determine the Denver area TOC's functional requirements and associated responsibilities.

- Determine the most appropriate systems and technologies to satisfy the TOC's identified functions and responsibilities.
- Develop an implementation timeframe and phased scheduling approach for the TOC and its associated systems.
- Determine the appropriate level of personnel required to staff the TOC.
- Determine the most appropriate TOC location.
- Assess communications needs within the TOC's operations.
- Prepare design documents, plans, strategies and an integrated systems architecture for the Denver area TOC.
- Prepare a preliminary TOC building architectural and civil/site design.

Building on these current activities, the following main tasks will be included in the ongoing TOC implementation process:

1) Review and finalize system and architectural designs (CDOT/CSP/FHWA/consultant team).
2) Develop bid documents, request proposals, and select equipment (hardware and software) supplier(s) (CDOT/CSP/FHWA, with consultant support).
3) Develop bid documents, request proposals, and select construction firm (CDOT/CSP, with consultant support).
4) Construct TOC (construction firm).
5) Deploy TOC hardware and software equipment (supplier/CDOT).
6) Acceptance testing and commissioning (CDOT/CSP/supplier).
7) Phased TOC implementation of chosen systems and technologies (various suppliers, with CDOT and CSP).

One of the main issues concerning the Denver area TOC is the appropriate level of involvement by the public and private sectors. The potential areas for private sector TOC involvement are design, construction, implementation, operation and maintenance activities. Public and private sector roles have been identified in the TOC's Scope of Work above, in the areas of design, construction and implementation.

However, there is also scope to examine the potential for public-private partnerships. For example, it is possible that the TOC could be implemented under a build/operate contract. Alternatively, the TOC could be built through a conventional construction contract

approach (as outlined above), with a subsequent bid for operational services to be provided by a private sector firm. The TOC operating contract should be rebid periodically if this approach is used. Opportunities for private sector input to TOC operations will be assessed further as the design effort progresses.

Project Schedule and Cost

The project approach presented above has outlined a series of tasks that will advance this activity through to full system implementation and operation. These can be grouped into four main areas with corresponding schedule and cost estimates, as follows:

		Duration	Cost
1)	Needs analysis, functional requirements and system design (current consultant team)	12 months	$650,000
2)	Design review and supplier and construction firm selection (SOW Tasks l-3)	9 months	$180,000
3)	TOC Construction and equipment (hardware and software procurement and installation for operations evaluation (SOW Tasks 4-5)	18 months	$7,000,000
4)	TOC acceptance testing and commissioning	6 months	$300,000
	TOTAL:	45 months	$8,130,000

It is anticipated that TOC construction activities will begin in 1995, with completion in 1996 or 1997. Initial equipment procurement will also begin in 1995 and is expected to continue through late 1996. Subsequent, phased implementation of the Denver area's chosen systems and technologies is reflected in the other activities outlined within this Master Plan.

Project Funding

CDOT's lead role in this activity will also entail them to be the partner responsible for seeking funding support. The majority of funding for the TOC implementation is expected to be from federal contributions. Additional funding from the State of Colorado due to CSP's participation is highly likely.

CDOT could also explore the potential for public-private partnerships. It is possible that the TOC could be constructed under a build/operate contract scenario as described previously. In addition, CDOT could seek arrangements with private sector companies concerning in-kind contribution to this activity. This could involve inviting the private sector to make proposals for provision of equipment which benefits the supplier, as well as the overall TOC operation.

TRAFFIC OPERATIONS CENTER EXPERT SYSTEM

Objective

This activity will focus on the development of an expert system for the TOC's initially implemented and planned future functions. A knowledge-based system will be developed in a phased approach, providing increasingly automated support for the TOC operator. Among the functions that will be assessed for integration are the traffic control, demand management, traveler information, and ramp control strategies. The system will initially provide advisory output and will be refined to provide fully-automated responses.

Priority

Implementation of the expert system is important to the overall success of the Denver area TOC. The ongoing expansion and enhancement of the TOC will ultimately entail functions of such variety and complexity that they are beyond the practical scope of human management and control. The design and establishment of the TOC expert system will assist the TOC operator's decision making process by providing automated support capabilities. Therefore, this activity will help to achieve overall system optimization on the Denver metro area road network. As this activity represents an advanced IVHS feature, it has been included for primary implementation during the medium-term timeframe. However, some initial expert system features may be realized in the short-term.

Applicable IVHS Goals

This activity will primarily address the Denver area IVHS goals which follow:

- Reduce congestion/improve mobility.
- Increase transportation safety.
- Minimize effects of incidents.
- Integrate existing operations and IVHS activities.
- Provide real-time travel information
- Provide operational improvements through technology.

Activity Interrelationships

This activity relies on the establishment of the Denver area TOC. Since the TOC provides a focal point for a number of traffic control and traffic management approaches, it is a prerequisite for the use of any automated expert support systems.

In addition, this activity will be significantly enhanced by the prior implementation of the following:

- Collection of real-time traffic volume and speed information.
- Expanded freeway ramp metering.
- TOC database integration.
- Develop permanent communications network.
- Disseminate travel information region-wide (e.g., HAR, VMS, RDS, videotex, audiotex, etc.).

Other potential activities are interdependent with the deployment of a TOC expert system within the Denver TOC. These include:

- Data fusion.
- Incident detection and management.
- Dynamic route guidance.
- Maintenance fleet management systems.
- Adaptive traffic control.
- Fourth generation signal control.

Approach

Initially, the efforts of this activity will focus on traffic control, incident management, demand management, traveler information, and ramp control strategies. Since most of these strategies rely on the establishment of the TOC, the TOC's managing authority will be the primary responsible agency. At this time, it seems likely that CDOT or CSP will manage the TOC's traffic management, incident management and information dissemination activities, and therefore will be the lead agency overseeing this effort.

In particular, responsibility for coordinating this activity should be placed with the new Systems Engineer position within the TOC. This would involve developing and maintaining software to support signal processing, traffic analysis and prediction, and traveler information aspects of the TOC operation. The position would also be in charge of developing software and hardware systems which enhance information interface capabilities between control consoles, and other traffic control and operations facilities.

In addition, the CDOT/CSP lead role will be complemented by those agencies involved with the TOC expert system's initially implemented and planned future functions. Within each of these functions, there is also scope to examine the potential for public-private partnerships in the implementation and application of TOC expert systems, particularly where these will support private ATIS efforts. Some potential functions and the affiliated responsible agencies include:

- Traffic Control (CDOT, CSP, involved community/jurisdiction).
- Ramp metering (CDOT).
- Traffic signal system coordination (involved community/jurisdiction, e.g., DRCOG, CDOT, Denver, Aurora, Arvada, etc.).

- Demand and Fleet Management
  - Computer-aided dispatch system (involved agency, e.g., RTD, CDOT, CSP, etc.).
  - Ride-sharing commuter assistance programs (e.g., RTD, DRCOG, Ride Arrangers, etc.).

- Traveler Information
  - Development of a common database for ATIS initiatives (CDOT, private sector).
  - VMS, HAR reports (CDOT).
  - RDS broadcasting (CDOT, private sector).
  - Teletext/cable TV (traffic reporting services, e.g., Shadow Traffic, Metro Traffic, etc.; private sector).
  - Videotex (private sector).
  - Audiotex (RTD).

Scope of Work (SOW)

Implementation of expert systems will likely be undertaken in a phased approach as needs arise or are predicted. The following tasks are representative of the scope of work associated with this effort:

1) Prepare an inventory of potential expert system applications (CDOT/CSP).

2) Prioritize and select expert system applications (CDOT/CSP/Systems Engineer).

3) For each application selected, the Systems Engineer with CDOT/CSP and affiiated agencies will address the following tasks:

   - Evaluate the operating system(s) hardware and software needs.

   - Review available commercial off-the-shelf software (COTS) packages and previous work, including liaison with bodies experienced in such systems.

   - Determine functional requirements for specific software programming needs.

   - Determine functional requirements for associated hardware and equipment needs.

   - Assess communications needs (and the extent to which they are met or unmet) within the expert system's operations (e.g., field equipment to TOC, operator workstation to TOC computer, etc.).

   - Prepare design documents and associated materials for the deployment of each expert system within the Denver area TOC.

4) Review and refine system design (CDOT/CSP/Systems Engineer/Affiliated Agency).

5) Software development or acquisition (CDOT/CSP/Systems Engineer/Affiliated Agency).

6) Develop bid documents, request proposals, and select hardware equipment supplier, if necessary (CDOT/CSP/Systems Engineer/Affiliated Agency).

7) Deploy expert system's software and hardware for operational evaluation, if necessary (CDOT/CSP/Systems Engineer/Affiliated Agency/Supplier).

8) Refine expert system operational procedures and functions, as required (CDOT/CSP/ Systems Engineer/Affiliated Agency).

9) Ongoing maintenance and enhancement (Systems Engineer).

As outlined above, CDOT and CSP will be the primary organizations responsible for implementation of any expert systems within the TOC, using guidance provided by the Systems Engineer and affiliated agencies, as funding becomes available. In addition, all operating and maintenance activities will be conducted by the Systems Engineer as appropriate. Ongoing system enhancements will be added as the TOC expert system expands in functionality.

Within the development of the TOC expert system, the potential exists for a number of public-private partnerships, particularly where these will support private ATIS efforts. In a more conventional manner, private sector firms specializing in systems/software engineering could be awarded contracts to perform expert system activities. Private sector involvement would encompass the Systems Engineer's responsibilities in SOW Tasks 3-9. Private sector involvement of this nature would occur if the Systems Engineer and CDOT/CSP determine that this is a reasonable course of action to pursue. Possible reasons for this decision include the TOC expert system's overall implementation timetable, System Engineer's availability, level of difficulty, and cost implications. In the event that the Systems Engineer position is not created, private sector involvement will be sought to fulfill these tasks. Within both of these possible scenarios, CDOT/CSP would need to develop procurement documents, request proposals, and select a consultant

Project Schedule and Cost

The project approach presented above has outlined a series of representative tasks that will advance expert system concepts through to full implementation and operation. However, it is anticipated that a number of expert systems will ultimately be required to support the TOC's various functions. The level of complexity of each system and the time at which it is required will vary. These variations will then determine each system's individual project schedule and cost.

Therefore, due to this activity's variability, a lump sum per annum budgeting approach is recommended. It is proposed that CDOT set aside $375,000 per year for a four-year

period to cover this activity's work scope. This would begin when the TOC's operations are fully underway. As project scopes are defined in more detail, this per annum budgeting approach will be refined to match the revised work

Project Funding

CDOT and CSP's lead roles in this activity will also entail them to be the partner responsible for seeking funding support Funding sources for this activity include federal funds and state funds.

CDOT/CSP could also seek arrangements with private sector companies concerning in-kind contributions to this activity. This could include unpaid software or equipment deployment by firms wishing to test new systems in a real-world environment, showcase their products, or provide a basis for follow-up ATIS ventures. Private firms may be particularly willing to provide data analysis or fusion software packages that assemble TOC-collected data in a format suitable for commercial ATIS dissemination.

Objective #2
Improve the Coverage and Scope of Traffic Data Collection

Activities

Collection of Real-Time Traffic Volume and Speed Information

Advanced Arterial Surveillance

Dial-in Data Collection System

Expand Closed Circuit Television (CCTV) Coverage

COLLECTION OF REAL-TIME TRAFFIC VOLUME AND SPEED INFORMATION

Objective

This activity will involve research, evaluation and deployment of freeway-related vehicle detection technologies meeting the Denver area's specific needs. In particular, this activity will implement a comprehensive, network-wide, real-time traffic information collection system. A vehicle detection network is required to accurately measure basic traffic parameters of volume (or flow rate), measured in vehicles per hour, speed, measured in miles per hour; lane occupancy, measured in percentage; and vehicle classification, typically measured by the number of axles.

This activity would complete a system of vehicle detectors along all freeway routes where traffic monitoring is desired. This detailed picture of traffic conditions on the freeway system will support the following functions:

- Determining existing traffic conditions.
- Automatically detecting incidents.
- Providing traveler information.
- Implementing appropriate traffic control strategies.
- Developing a historical database for planning purposes.

Priority

The implementation of this activity is of major importance to the overall success of IVHS in the Denver area. The real-time traffic information collection system provides the data on which several ATMS and ATIS efforts will be based. Due to the overall importance of this activity, it has been included for implementation within the scope of the Early Action Plan.

Applicable IVHS Goals

This activity will primarily address the Denver area IVHS goals which follow:

- Reduce congestion/improve mobility.
- Minimize effects of incidents.
- Integrate existing operations and IVHS activities.
- Provide opportunities for academic research and private sector participation.
- Provide operational improvements through technology.

Activity Interrelationships

The establishment of the Denver TOC is central to this activity since it will provide a focal point for the metro area's IVHS-related information collection efforts. The TOC will provide the physical facility to collect real-time or summarized traffic information from every type of detection equipment implemented.

In addition, other potential activities are interdependent with this activity. These include:

- Expanded freeway ramp metering.
- . Create temporary communications to key locations.
- Develop permanent communications network.
- Public-private partnerships.

The following activities will be significantly enhanced by the implementation of a real-time traffic information collection system:

- Incident detection and management.
- Develop cooperative exchange system with TV and radio traffic information services.
- Disseminate travel information region-wide (e.g., HAR, VMS, RDS, videotex, audiotex, etc.).

Approach

This activity will focus on the Denver area freeway system. Therefore, CDOT will be the lead agency responsible for managing the effort, possibly with FHWA support It is anticipated that the majority of the work will be performed by private firms under contract to CDOT. However, some tasks will be undertaken by CDOT personnel.

Scope of Work (SOW)

Tasks within this activity need to be closely coordinated to ensure the overall success of the effort. The following main tasks will be included in the scope of work:

1) Prepare an inventory of current vehicle detection equipment and locations in the Denver metro area (CDOT).

2) Develop procurement documents, request proposals, and Select consultant (CDOT).

3) Once selected, the consultant, with CDOT, will address the following tasks:

   - Evaluate the Denver area's additional freeway data collection needs.

- Identify and assess current locations which could enhance and ultimately complete the Denver area freeway vehicle detection system.
- Review available technologies (e.g., inductive loop, infrared, microwave, optical, acoustic, video image processing, etc.) and previous work, including liaison with bodies experienced in such systems.
- Determine functional requirements for the vehicle detection equipment.
- Determine the most appropriate detection equipment and locations for the Denver metro area.
- Determine the appropriate level of data processing between field location (decentralized) and the Denver TOC (centralized).
- Assess communications needs between detection equipment and TOC.
- Prepare design documents, plans and an integrated systems architecture for data collection and transfer within the Denver area.

4) Review and refine system design (CDOT/Consultant).

5) Develop bid documents, request proposals, and select equipment supplier (CDOT/ Consultant).

6) Identify testing locations and deploy new detection equipment (limited order) for operational evaluation, if necessary (CDOT/Supplier).

7) Evaluate trial deployment and refine system architecture and operational procedures, as required (CDOT/Consultant).

8) Extend equipment supply order for widespread system implementation and ongoing maintenance and enhancements (CDOT).

As outlined above, CDOT will be responsible for installation of the real-time traffic information collection system, using guidelines provided by the supplier, as funding becomes available. In addition, all operating and maintenance activities will be conducted by CDOT. However, there is also scope to examine the potential for a public-private partnership in the deployment of data collection devices, particularly where these will support private ATIS efforts. Ongoing system enhancements will be added as the real-time traffic information collection system expands in both size and functionality.

In addition, there are some projects currently underway in the Denver area which involve the installation of inductive loops along the freeway system. It is important that these projects are coordinated with each other and with elements of this activity. The following projects should be viewed in a broader, region-wide perspective to ensure overall program compatibility with the real-time traffic information collection system.

Expanded Freeway Ramp Metering System - CDOT is currently in the process of expanding its freeway ramp metering system at a number of locations throughout the Denver metro area. In addition, CDOT is upgrading the ramp metering computer system to obtain greater control and monitoring flexibility and provide improved software for graphical displays of freeway speeds. This upgrade will include the current ramp metering network (28 locations primarily situated in the east and south portions of the metro area along I-25 and I-225) as well as the new ramp metering locations. See Figure A2.

North I-25 Traffic Management System - CDOT, the Regional Transportation District (RTD), and the City and County of Denver are cooperatively developing a two-lane reversible bus and HOV facility in the North I-25 corridor between 70th Avenue and 20th Street. When completed, the bus/HOV facility will include a state-of-the-art Traffic Management System with computerized control, variable message signs, an extensive network of loop detectors, closed circuit television (CCTV) monitoring and computer-aided command and control capabilities. Inductive loop vehicle detectors will be provided on both the bus/HOV express lanes and along the I-2.5 mainline lanes in accordance with CDOT standards.

Freeway Inductive Loop System - In conjunction with recent resurfacing projects, CDOT has installed a number of inductive loops along the freeway system. The majority of these loop stations are located along I-25 and its associated on-ramps between Speer Boulevard and Colorado Boulevard. These stations do not currently have any detection equipment or communications hardware installed. These efforts should be included within both the real-time information collection system and expanded ramp metering system.

Project Schedule and Cost

The project approach presented above has outlined a series of tasks that will advance this activity through to full system implementation and operation. These can be grouped into five main areas with corresponding schedule and cost estimates, as follows:

	Duration	cost
1) CDOT preparatory work (SOW Tasks l-2)	4 months	$30,000
2) Needs analysis, functional requirements and system design (SOW Task 3)	12 months	$600,000
3) Design review and supplier selection (SOW Tasks 4-5)	4 months	$80,000
4) Limited procurement, trial implementation and evaluation (SOW Tasks 6-7)	6 months	$500,000
5) Full system implementation (SOW Task 8)	12 months	$4,000,000
TOTAL:	38 months	$5,210,000

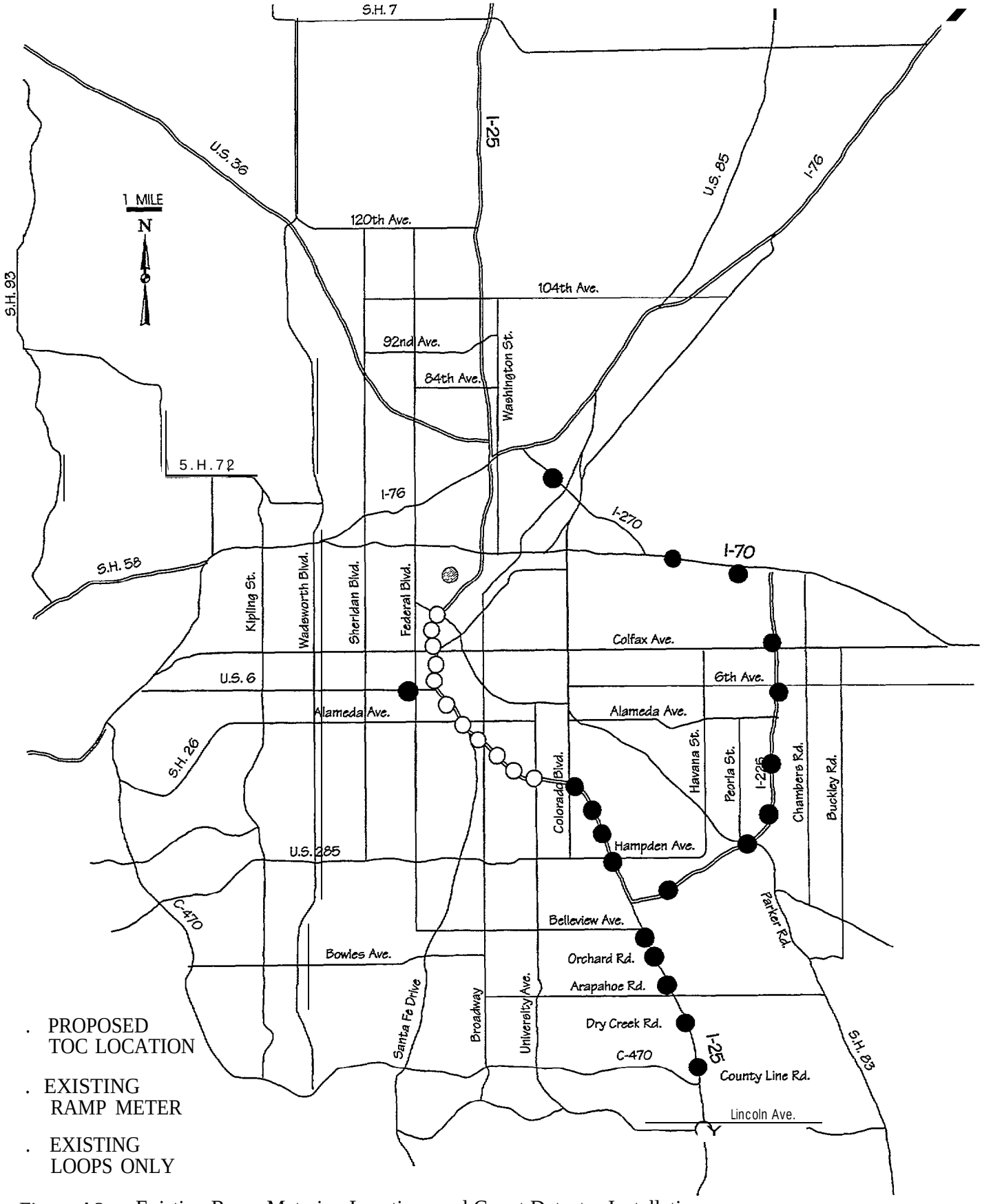


Figure A2 Existing Ramp Metering Locations and Count Detector Installations

If only proven available equipment is used, trial implementation and evaluation will be unnecessary and the estimates may be reduced to 32 months and $4,710,000 for schedule and cost, respectively. As project scopes are defined in more detail, the estimates will be refined to match the revised work.

Project Funding

CDOT's lead role in this activity will also entail them to be the partner responsible for seeking funding support Funding sources for this activity include federal funds and state funds.

CDOT could also seek arrangements with private sector companies concerning in-kind contributions to this activity. This could include unpaid equipment deployment by firms wishing to test new systems in a real-world environment, showcase their products, or provide a basis for follow-up ATIS ventures. In England, for example, one private company has developed a subscription traffic reporting service by installing its own network of infrared speed sensors. A license was granted by the U.K. Department of Transport for the deployment of this equipment, as well as for the sale or lease of the system's in-vehicle display devices. A similar approach may be operable in the Denver area. However, CDOT will need to establish strict guidelines for this policy (if initiated) before allowing such private sector infrastructure deployments to proceed.

ADVANCED ARTERIAL SURVEILLANCE

Objective

This activity will involve deployment of IVHS technologies meeting the Denver area's specific needs as they relate to arterial surveillance. The objectives of applying these technologies will be to enhance data collection facilities on the arterial street system. This will complement the freeway monitoring system, providing more complete, network-wide traffic data and supporting informed traffic and incident management actions.

A number of approaches with potential for arterial surveillance application are currently under investigation in the U.S., including video image processors, radar monitoring systems and probe-based data collection techniques. Within five years, it is anticipated that some of these technologies will be fully developed and proven. This project will evaluate and select appropriate systems for use in the Denver metro area. The project is therefore seen primarily as a deployment effort, rather than as a research and development venture.

Priority

This activity is important to support some of the more advanced components of IVHS in the Denver area. Advanced arterial surveillance techniques offer an excellent opportunity to more fully integrate the arterial street system with the freeway system, as well as to improve traffic operations on the arterials themselves. A more complete and coordinated network-wide surveillance system has the potential to increase the efficiency of traffic and incident management decisions. This area-wide knowledge of conditions will provide particular input to activities such as preplanned incident diversion routes and advanced signal timing programs.

Applicable IVHS Goals

This activity will primarily address the Denver area IVHS goals which follow:

- Reduce congestion/improve mobility.
- Integrate existing operations with IVHS activities.
- Provide opportunities for academic research and private sector participation.
- Provide operational improvements through technology.

Activity Interrelationships

The TOC is central to this activity since it will be a focal point for the area's IVHS-related information collection efforts. The TOC will provide the physical facility to collect real-time or summarized traffic data from every type of surveillance equipment implemented. The TOC will also act as an information clearinghouse, disseminating the

arterial surveillance data to area agencies, and to the general public through ATIS mechanisms.

At this time, the specific nature of the Denver area TOC's role in this activity has not been determined. It is possible that the TOC could be connected directly to the arterial surveillance equipment, similar to the region's freeway monimring facilities. Alternatively, the arterial surveillance equipment could be connected to local jurisdictional facilities, with information sharing capabilities exchanging data between these and the TOC. This and other related issues will be addressed as part of this activity.

In addition to the support provided by the TOC, prior implementation of the following activities will significantly enhance this advanced arterial surveillance effort:

- Collection of real-time traffic volume and speed information.
- Develop permanent communications network.

Other activities will significantly benefit from the implementation of an advanced arterial surveillance system. These include:

- Incident detection and management.
- Preplanned incident diversion routes.
- Dynamic route guidance.
- Adaptive traffic control.

Approach

This activity will focus on providing advanced surveillance and data collection techniques along the Denver area's arterial street system. Currently, the Denver Regional Council of Governments (DRCOG) coordinates a regional traffic signal system improvement program aiming to implement cost-effective traffic signal timing and coordination improvements over the 1993-98 period (References 1 and 8). A similar effort will be involved in deployment of arterial surveillance in the Denver area. This suggests that DRCOG would be one logical lead agency which could oversee this effort.

In accepting this role, DRCOG would become responsible for coordinating and overseeing implementation of an arterial surveillance program in the region. It is anticipated that deployment would take place on a corridor-by-corridor basis, with the most critical arterials receiving attention first. Initial implementation should be along one or more of the most congested corridors as depicted in Figure A3 (Reference 1). With regard to equipment installation on a particular arterial, the jurisdiction or agency which maintains the facility would take charge of the local effort. In cases where the arterial passes through different jurisdictions, DRCOG's coordination efforts would ensure consistency and compatibility along the corridor.

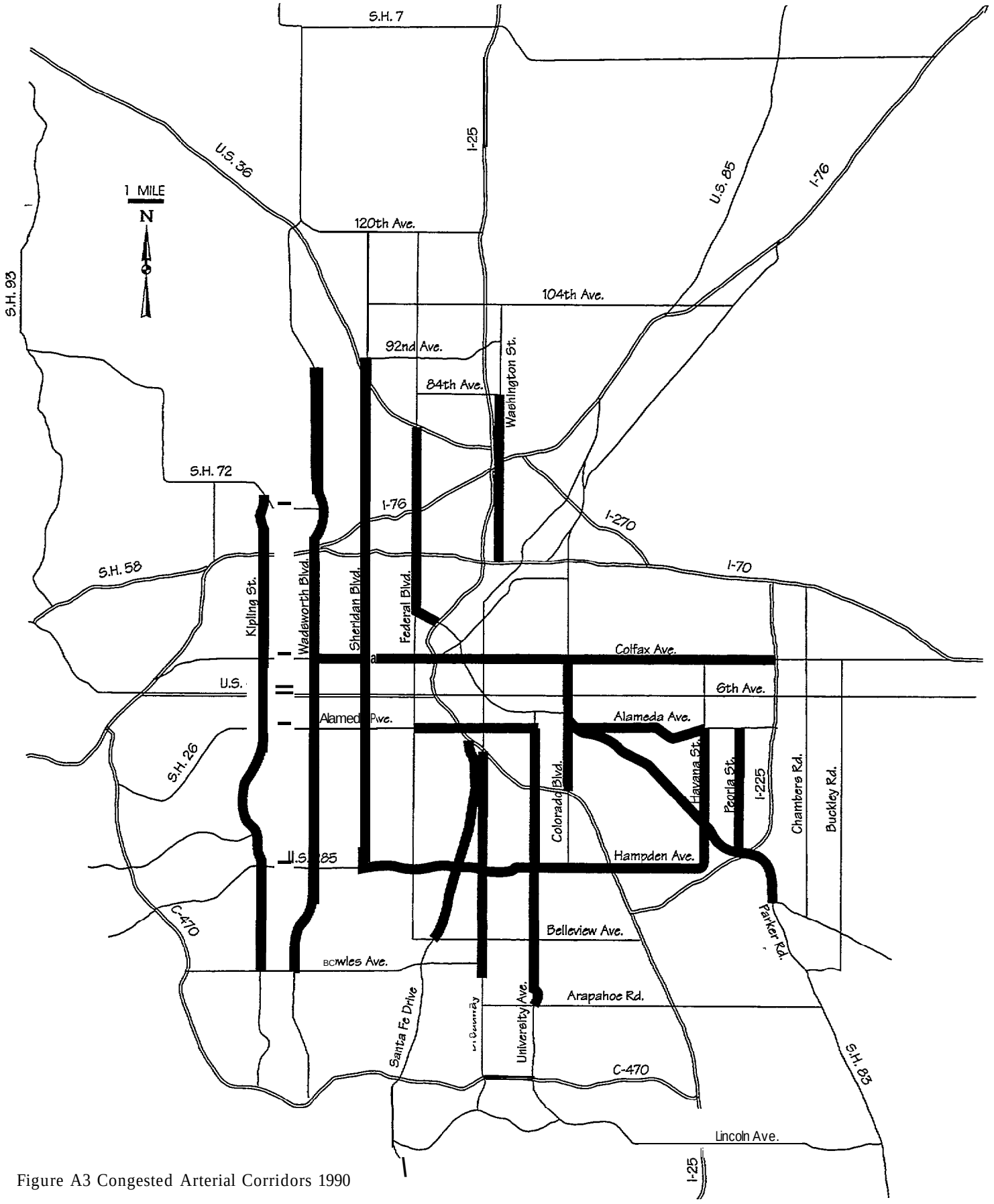


Figure A3 Congested Arterial Corridors 1990

It is anticipated that data and communication ties between the advanced arterial surveillance systems and the Denver area TOC will be established. These may be direct links, or data exchanges between the TOC and local authorities' data collection centers. Regardless, CDOT will need to get involved at a significant level of detail at this point. Close working relationships between CDOT, city and county traffic departments, corridor management teams and other agencies could be coordinated by DRCOG.

It is likely that a significant proportion of the work would be performed by private firms under contract to the appropriate jurisdiction or agency. Other tasks would be undertaken by DRCOG, CDOT and the affiliated agencies' personnel as required.

Scope of Work (SOW)

Implementation of advanced arterial surveillance systems will likely be undertaken in a phased approach reflecting prioritization of corridors in the metro area. The following main tasks are representative of the scope of work associated with this effort:

1) Review arterial traffic data needs and identify potential corridors for surveillance (DRCOG/CDOT/local jurisdiction).

2) Prioritize and select corridor locations (DRCOG/CDOT/local jurisdiction).

3) For each corridor selected, the following tasks will be addressed:

   - Develop procurement documents, request proposals, and select consultant (DRCOG/CDOT/local jurisdiction).
   - Prepare design documents and specifications for the deployment of arterial surveillance in the corridor (consultant).
   - Review and refine system design (DRCOG/consultant/local jurisdiction).
   - Develop bid documents, request proposals, and select system supplier (DRCOG/consultant/local jurisdiction).
   - Deploy arterial surveillance system software and hardware (supplier/local jurisdiction).
   - Implement links to TOC (CDOT/local jurisdiction).
   - Integrate arterial data in TOC systems (CDOT).

As outlined above, two processes would be involved in each arterial corridor deployment effort. The first would recruit a consultant for design, while the second would select a system supplier. However, recognizing the costs associated with selecting contractors, DRCOG may wish to explore the use of a limited number of contractors in this effort. For example, the Denver area could be divided into subregions. A bid process would then

select a design consultant for each subregion, responsible for all arterial surveillance design efforts in that area. Similarly, a supply firm could be selected for each subregion.

The ability to adopt this approach will depend, in part, on the consistency of arterial surveillance equipment used throughout the metro area. It would also require an agreement between all of the affected agencies in each subregion.

Project Schedule and Cost

The project approach presented above has outlined a series of representative tasks that will advance arterial surveillance concepts through to full implementation and operation. However, it is anticipated that a number of arterial corridors will ultimately be instrumented to support the Denver metro area's network monitoring activities. The level of complexity of each arterial and the time at which equipment will be installed will vary according to the prioritization of corridors. The number of corridors to be instrumented will be established as an initial element of this activity.

Therefore, due to this activity's variability, a lump sum per annum budgeting approach is recommended. This would set aside $1,500,000 per year over a four-year period to cover this activity's work scope. These monies would be used to fund design, supply and installation contract costs, as well as costs associated with DRCOG's coordination of the effort and input from other metro area agencies.

This project could begin in the short to medium term as many of the advanced arterial surveillance technologies are already being tested in various locations across North America. If earlier opportunities arise for arterial surveillance deployment, the benefits of network-wide data collection will make this worthy of consideration.

Project Funding

DRCOG's leadership in this activity will involve seeking funding support for advanced arterial surveillance. Equipment is to be installed on arterial streets operated not only by CDOT but also by city and county authorities, and this will be undertaken in large part to benefit overall metro area operations. Local authorities should not bear the complete funding burden. DRCOG should look to identify funds from local, state, and federal sources.

DRCOG and the affiliated agencies could also seek arrangements with private sector companies concerning in-kind contributions to this activity. This could include equipment deployment by firms wishing to demonstrate new systems in a real-world environment. Some firms may also be willing to install equipment on arterials in support of commercial ATIS ventures.

DIAL-IN DATA COLLECTION SYSTEM

Objective

This activity will seek to enhance information availability at the TOC through the establishment of a cellular telephone dial-in data collection system. This service will allow the public to relay traffic and incident information directly to the Denver TOC. The dial-in approach has demonstrated a proven track record of success in other metropolitan areas and is supported by the Colorado Incident Management Coalition (CIMC) (Reference 6). Therefore, this activity should be coordinated with the efforts of the CIMC subgroup addressing cellular call-m services.

The CIMC is proposing the establishment of an Emergency Dial 911/Roadway Information Dial 7 7 call-in service. It is expected that these efforts will also be closely coordinated with existing roadway and incident information telephone numbers established by various radio and television stations. For example, radio station KOA (AM 850) currently operates a *85 call in system for drivers to report incidents or unusual congestion. This information is related to on-air listeners at regular intervals during peak drive times.

Priority

This activity can play a valuable role in the implementation of IVHS in the Denver metro area. In the early years, detector and CCTV coverage of the region will be limited, and cellular phones will provide an important method of detecting and verifying incidents. It is anticipated that a high level of motorist participation will also result in increased appreciation and support of IVHS. Due to the overall importance of this activity, and the relative ease with which it can be implemented, it has been included for implementation within the scope of the Early Action Plan.

Applicable IVHS Goals

This activity will primarily address the Denver area IVHS goals which follow:

- Reduce congestion/improve mobility.
- Increase transportation safety.
- Minimize effects of incidents.
- Provide real-time travel information.
- Make maximum use of existing, proven technologies.

Activity Interrelationships

The establishment of the Denver TOC is seen as a prerequisite to this activity since it will provide a focal point for the cellular call-in system. Without the TOC in operation as a coordinating facility, it is believed that the number of calls received will be simply too great to handle.

The CIMC recommends that the Denver TOC act as the receiving point for *77 phone calls. This will allow roadway information to be received at a central location, resulting in improved response. At this time, it is anticipated that the existing 911 dispatch center, operated by CSP at 700 Kipling will relocate to the TOC. Existing 911 calls within Denver City Limits would continue to be received by the Denver Police Department, but with increased coordination and cooperation with the Denver area TOC.

Several other IVHS activities are dependent in part on this activity and the data it will provide. These include:

- Incident detection and management.
- Develop cooperative exchange system with television and radio traffic information services.
- Disseminate travel information region-wide (e.g., HAR, VMS, RDS, videotex, audiotex.

Approach

Current regional 911 dispatch centers are operated by CSP at 700 Kipling Street and the Denver Police Department within the Denver City Limits. It is anticipated that these groups will continue to operate the current system as the newly formed *77 roadway information service is established within the Denver TOC and combined with the CSP 911 call taking unit. CSP personnel are experienced in responding to such calls, and CSP is therefore expected to be the lead agency overseeing this effort within the Denver TOC.

Since this cellular call-in service will be located within the TOC, CDOT is also likely to play a significant role in the implementation of this activity. In addition, close coordination with the existing 911 dispatch centers (operated by CSP and the Denver Police Department) as well as the various news media telephone call-ins will be necessary. It is anticipated that the majority of the work will be performed by CSP personnel, with support from appropriate telephone service providers.

Scope of Work (SOW)

In order to accommodate the large number of calls expected, the dial-in system will be introduced after the implementation of the Denver TOC. The following main tasks will be included in the scope of work:

1) Review previous experience with dial-in data collection systems (CSP/CDOT).

2) Define scope of the dial-in system (CSP/CDOT).

3) Develop operational procedures for data collection and verification (CSP/CDOT).

4) Implement telephone system (service provider).

5) Develop and implement marketing plan (CSP/CDOT).

6) Implement freeway signing program (CDOT).

7) Trial operation and system refinement (CDOT/CSP).

8) Full-time system operation.

Project Schedule and Cost

The project approach presented above has outlined a series of tasks that will advance this activity through to full system implementation and operation. These can be grouped into four main areas with corresponding schedule and cost estimates, as follows:

		Duration	Cost
1)	Review previous experience (SOW Task 1)	3 months	$15,000
2)	Definition of scope and operational procedures (SOW Tasks 2-3)	6 months	$40,000
3)	System implementation and marketing (SOW Tasks 4-6)	6 months	$75,000
4)	Trial operation and evaluation (SOW Task 7)	3 months	$30,000
		TOTAL: 18 months	$160,000

The CIMC has estimated that this organized cellular dial-in data collection system will cost $90,000 per year to operate. This figure is expected to cover the work outlined in SOW Task 8.

It is anticipated that work for this activity will get underway in the short term. This will allow the dial-in system to go into operation as an initial element of the TOC's activities.

Project Funding

As partners in this activity, CSP and CDOT will jointly be responsible for seeking funding support. Some federal support may be available as part of the TOC implementation effort. Federal contributions will likely need to be supplemented by state funds from CDOT and CSP appropriations.

CSP and CDOT could also seek arrangements with private sector companies concerning in-kind contributions to this activity. In particular, local telephone carriers could be encouraged to support this activity by contributing to the costs associated with a call-in to the Denver area TOC. This type of contribution would enhance the carrier's public relations efforts in the Denver area, which may act as an incentive for participation.

CDOT and CSP could also negotiate an agreement with the telephone service provider, for example by offering TOC-collected data in return for the company's input. These data could then be used by the company to operate a commercial ATIS venture.

EXPAND CLOSED CIRCUIT TELEVISION (CCTV) COVERAGE

Objective

This activity will focus on efforts to expand CCTV coverage in the Denver area. The first set of CCTV cameras will be installed as part of the North I-25 Bus/HOV corridor project. In this activity, further CCTV cameras will be installed, increasing network coverage in the metro area. These CCTV cameras will be used for surveillance of traffic conditions and for incident verification. Images from CCTV cameras will also be presented to travelers via television, when needed.

Visual confirmation of incidents by CCTV is an important component of Denver's traffic and incident management systems. Once a disruption in traffic flow is detected, visual observation is often necessary to determine the location and nature of the incident. In some cases, different locations for the same incident are reported by the public. CCTV camera coverage provides a means of visual verification to confirm the actual location of an incident, and assists in the dispatching of the appropriate emergency response equipment.

Initially, additional CCTV cameras should be installed at high accident locations or capacity bottlenecks along the freeway system in the area such as the I-70 Stapleton Airport tunnels, along I-25 at the Broadway/Santa Fe Drive interchange complex or along I-25 at the Denver Tech Center. Eventually, CCTV cameras should be placed along all the freeways in the region and at key arterial locations near the freeways. In addition, several local television stations have installed CCTV cameras at fixed locations to view traffic conditions along the freeway. Joint utilization of these CCTV images, particularly for major incidents, provides an excellent opportunity for public-private partnerships.

Priority

This activity is seen as another foundation for the implementation of IVHS in the Denver area. Current automated incident detection algorithms are not sufficiently accurate to rely on without a cross-check. CCTV camera surveillance is an available and reliable method of incident verification. Deployment of CCTV cameras at the appropriate locations will also assist in the dispatching of the correct type of emergency response equipment to the incident site. Due to the overall importance of this activity, it has been included for implementation within both the CIMC's recommendations and the Early Action Plan.

For the longer-term, CCTV technology is expected to support automated data collection through video image processing. This is currently being explored in a number of areas, and is advantageous in that it does not require installation of equipment in the highway surface.

Applicable IVHS Goals

This activity will primarily address the Denver IVHS goals which follow:

- Reduce congestion/improve mobility.
- Increase transportation safety.
- Minimize effects of incidents.
- Provide real-time travel information.
- Reduce potential hazardous impacts.

Activity Interrelationships

The establishment of the TOC is central to this activity since it will provide a focal point for the reception and review of CCTV video transmissions. From the CCTV monitors within the TOC, a coordinated and efficient incident response effort can get underway. Establishment of a communications network is also key to this activity. The communications network is required to carry the CCTV images back to the TOC reliably and at an acceptable cost.

In addition, other potential activities are interdependent with this activity. These include:

- TOC database integration.
- Data fusion.
- TOC expert system.

Activities which will be significantly enhanced by CCTV expansion include:

- Teletext and cable TV services.
- Cooperative exchange with television and radio.
- Incident detection and management.

Approach

Since this activity will focus on the freeway system, CDOT is expected to be the lead agency responsible for managing the effort. It is anticipated that the work will follow a traditional approach, in which the system design will be prepared by a consultant, and implementation will be undertaken by a contractor.

Scope of Work (SOW)

The following main tasks are expected to be included in the scope of work:

1) Prepare an inventory of current CCTV camera equipment and locations in the Denver area, and determine additional CCTV coverage needs (CDOT).

2) Develop procurement documents, request proposals, and select consultant (CDOT).

3) Once selected, the consultant, with CDOT, will address the following tasks:

- Finalize locations to enhance the Denver area freeway CCTV system (e.g., high accident locations, capacity bottlenecks, strategic arterial locations near the freeways, etc.).
- Review alternative CCTV technologies and previous experience.
- Determine functional and performance requirements for system software and associated hardware.
- Assess communications needs and the suitability of the permanent communications network for the CCTV system operations.
- Prepare design documents, plans and specifications for the CCTV system within the Denver metro area.

4) Develop bid documents, request proposals, and select equipment supplier (CDOT/ Consultant).

5) System implementation and commissioning (supplier).

It is expected that CDOT will maintain the CCTV equipment, using guidelines provided by the supplier, following its initial implementation.

Project Schedule and Cost

The project approach presented above has outlined a series of tasks that will advance this activity through to full system implementation and operation. A corresponding schedule and cost estimates are presented below:

		Duration	Cost
1)	CDOT preparatory work (SOW Tasks l-2)	6 months	$50,000
2)	System design (SOW Task 3)	6 months	$200,000
3)	Design review and supplier selection (SOW Task 4)	4 months	$50,000
4)	System implementation and commissioning (SOW Task 5)	12 months	$1,000,000
	TOTAL	28 months	$1,300,000

This effort is expected to begin in the short term.

Project Funding

CDOT will be responsible for seeking funding support for this project. The majority of funds are expected to be drawn from federal sources such as IVHS monies set aside under ISTEA.

In addition, several television stations have installed CCTV cameras at fixed locations to view traffic conditions along the freeway. Joint utilization of these CCTV images, particularly for major incidents, provides an opportunity for public-private partnerships in this area. Please see the second activity under Objective #4 (Develop Cooperative Exchange System with TV and Radio...) for additional information.

Objective #3
Develop Computerized Data Handling and Monitoring Systems

Activities

TOC Database Integration

Data Fusion

Maintenance Fleet Management Systems

TOC DATABASE INTEGRATION

Objective

This activity will focus on the integration of the TOC's in-house and distributed database systems. Many of the ATMS, ATIS and incident management projects included within the Denver metro area IVHS Master Plan will ultimately use common databases associated with the TOC facility. This activity will implement the necessary database structure for both current and planned systems. These may include the ramp metering system, freeway vehicle detection efforts, environmental monitoring systems, fleet management and dispatch systems, incident management efforts, and various ATIS ventures. An appropriate database format will include central and distributed information processing needs, data communications requirements, and necessary redundancy efforts. Overall, this activity is intended to bring the various information databases together to make them functional and useful at the individual TOC workstation level.

Priority

This activity is important to the long-term success of IVHS in the Denver metro area. In particular, the efficiency of the TOC will depend in part on large amounts of data being stored, manipulated, and updated on a real-time basis. Therefore, early integration of the TOC's various database systems will provide a common ground from which to support all subsequent activities. Due to the overall importance of this activity, it has been included for implementation within the scope of the Early Action Plan.

Applicable IVHS Goals

This activity will primarily address the Denver IVHS goals which follow:

- Increase transportation safety.
- Minimize effects of incidents.
- Integrate existing operations and IVHS activities.
- Provide opportunities for academic research and private sector participation.
- Make efficient use of tax dollars.
- Provide operational improvements through technology.

Activity Interrelationships

This activity is primarily dependent on the implementation of the Denver area TOC and its associated IVHS components. Many of the TOC's ATMS, ATIS, and incident management efforts as well as CSP's integrated dispatching efforts will utilize computer databases. Integration of both in-house and distributed system databases will help to

achieve efficient TOC operations, by ensuring that all data are maintained in a consistent, easily transferable format.

In addition, this activity will be significantly enhanced by the prior implementation of the following IVHS program elements:

- Collection of real-time traffic volume and speed information.
- Expanded freeway ramp metering.
- Development of permanent communications network.
- Environmental monitoring systems.

Other potential activities can be undertaken in parallel with the integration of the TOC's database systems. These include:

- Maintenance fleet management systems.
- Incident detection and management.
- Develop cooperative exchange system with TV and radio traffic information services.
- Disseminate travel information region-wide.

Finally, the following activities will build on the TOC's integrated database facilities:

- Data fusion.
- TOC expert system.
- Dynamic route guidance.

Approach

The TOC's managing authority will be the primary responsible agency for this activity. At this time, it seems likely that CDOT will manage the TOC's ATMS and ATIS components, and will therefore be the lead agency for this effort. Substantial input will likely also be required from CSP.

In particular, responsibility for coordinating this activity should be placed with the new Systems Engineer position within the TOC. This would involve developing and maintaining software and hardware systems in a suitable structure to accommodate the appropriate level of database integration. The position would also be in charge of developing software and hardware systems which enhance information interface capabilities between control consoles, incident management agencies, and other facilities.

CDOT's lead role will be complemented by the involvement of other agencies associated with the multiple database integration. There is also scope to examine the potential for public-private partnerships in the implementation and application of database integration,

particularly where these will support private ATIS ventures. Some potential functions and related participant groups include:

- Traffic information and control
  - Vehicle detection systems (CDOT, private sector) ramp metering (CDOT).
  - Distributed traffic control facilities (local operating authorities).
  - Environmental sensors network (CDOT).

- Incident and fleet management
  - Geographically-coded information system network, allowing automatic identification of appropriate response agencies (CDOT, CSP, local police, fire, etc.).
  - Computer-aided dispatch system (RTD, CDOT, CSP, etc.).
  - Incident response plan record database (CDOT, CSP, fire, ambulance service, etc.).
  - GPS system (RTD, CDOT, emergency service vehicles, etc.).

- Traveler information
  - Common ATIS database (CDOT, private sector).
  - VMS, HAR reports (CDOT, CSP).
  - RDS broadcasting (CDOT, CSP, private sector).
  - Teletext/cable TV (CDOT, CSP, TV stations).
  - Videotex (private sector).
  - Audiotex (RTD).

Scope of Work (SOW)

The following main tasks are representative of the scope of work associated with this effort:

1) Identify potential components for system database integration (CDOT/Systems Engineer).

2) Prioritize and select systems for database integration (CDOT/Systems Engineer).

3) For each database integration effort undertaken, the Systems Engineer with CDOT and affiliated agencies will address the following tasks:

   - Identify all participating agencies.
   - Identify information and format required by each agency.
   - Evaluate overall hardware and software needs.
   - Determine functional requirements for the integrated database system.
   - Assess communications needs (and the extent to which they are met or unmet) within the integrated database system's operations.

4) Develop bid documents, request proposals, and select system developer/supplier (CDOT/ Systems Engineer).

5) Software development and supply of system hardware (contractor);

6) Deploy and commission integrated database system's software and hardware (Systems Engineer/affiliated agency/contractor).

7) Ongoing maintenance and enhancement (Systems Engineer).

There is again scope for private involvement and public-private cooperation in this activity. Private sector firms, with CDOT's guidance, may wish to develop integrated database capabilities for the TOC at their own expense, to provide a foundation for commercial ATIS initiatives. In a more conventional manner, private sector firms specializing in systems/software engineering could be awarded contracts to integrate the TOC's system databases.

Project Schedule and Cost

The project approach presented above has outlined a series of tasks representative of an individual TOC database integration effort. However, it is anticipated that numerous system databases will ultimately be integrated to support the TOC's various functions. The level of complexity of each system's integration and the time at which it is required will vary.

In addition, the close relationship inherent between the implementation of TOC components and subsequent system database integration affects both project schedule and cost. Since database integration relies on system implementation, integration will occur in parallel with the overall TOC timetable.

Therefore, due to this activity's variability and interdependency with other efforts, a lump sum per annum budgeting approach is recommended. It is proposed that CDOT set aside $100,000 per year for a five-year period to cover this activity's work scope. This would begin when the TOC is commissioned. As project scopes are defined in more detail, this per annum budgeting approach can be refined to match the revised work.

Project Funding

CDOT will be responsible for seeking funding support for this activity. The majority of funds are expected to be drawn from state and federal sources. Local funds may be applicable where database integration directly benefits a local authority in the metro area.

CDOT could also seek arrangements with private sector companies concerning in-kind contributions to this activity. In particular, private firms may be willing to support database integration efforts in order to ensure that resulting data formats support their commercial objectives.

DATA FUSION

Objective

This activity will involve fusion of the data received at the Denver area TOC from the many external systems to produce a single, reliable database. The TOC's data fusion activities will build upon the initial foundation established within the TOC database integration efforts.

The data fusion process assigns reliability and longevity weightings to alternative data sources, for example inductive loops, dial-in reports and CCTV images. Data fusion software will need to be developed to integrate data from these various sources at the TOC, including automatic input with default weightings plus operator input and override facilities. This will allow the most valid conclusions to be drawn when data from different sources conflict. This will be particularly important in areas such as calculation of link travel times for ATIS devices and analysis of congestion levels in incident response planning.

Priority

The implementation of this activity is important to support some of the Master Plan's longer-term components. The data fusion software will be utilized at the TOC to assist the operators in resolving data conflicts and assessing traffic conditions. This will provide the information needed for operation of advanced systems such as route guidance and improved automatic incident detection. Since this activity will follow on from the TOC database integration efforts, major data fusion activities will begin in the medium-term timeframe.

Applicable IVHS Goals

This activity will primarily address the Denver IVHS goals which follow:

- Increase transportation safety.
- Minimize effects of incidents.
- Integrate existing operations and IVHS activities.
- Provide opportunities for academic research and private sector participation.
- Provide operational improvements through technology.

Activity Interrelationships

This activity has a long-term interdependency with the Denver TOC. Since many of the TOC's ATMS, ATIS and incident management efforts will utilize common databases, functional integration of both in-house and distributed system databases will be required to support efficient operations. The data fusion process will build on this integration to

produce a single, reliable database to assist the TOC operators. The TOC will therefore provide the physical facility from which to perform integration and fusing of data from various external systems.

Other activities which will provide significant input to the data fusion effort include the following:

- Collection of real-time traffic volume and speed information.
- Expanded freeway ramp metering.
- Advanced arterial surveillance.
- TOC database integration.
- . Expand CCTV coverage.
- Dial-in data collection system.
- Environmental monitoring systems,

Several activities are themselves dependent on the TOC's data fusion process. These include:

- TOC expert system.
- Emergency service dispatching and routing.
- Dynamic route guidance.
- Adaptive traffic control.

Approach

This activity will build upon the foundation established within the earlier TOC database integration activities. This data fusion process will address the identification of logical results from multiple databases. Since most of these databases will reside in the TOC, the TOC's managing authority will be the primary responsible agency for this effort This implies overall leadership of the initiative by CDOT. Substantial input will also be required from CSP.

Within CDOT, responsibility for coordinating this activity should be placed with the new Systems Engineer position at the TOC. This role would involve overseeing development of software systems and hardware interfaces in a suitable structure to accommodate the desired level of data fusion.

Data fusion is a relatively new process which has only recently begun to find application in the IVHS environment. The complexities associated with data fusion, and the potential for research into alternative ways of combining data, have led to its investigation by several academic groups. This indicates that this activity may be suitable for participation of the new Colorado Transportation Institute (CTI).

More specifically, a university member of CTI could undertake software development for the data fusion system. Other CTI members would provide technical input to this work, which would be coordinated by the TOC Systems Engineer. This potential involvement of CTI is similar to the role being played by the Illinois Universities Transportation Research Consortium in the current ADVANCE project in Chicago.

Scope of Work (SOW)

It is anticipated that implementation of data fusion at the TOC will occur through a number of incremental modifications to operating software. As new technologies and systems are brought on line in the TOC, further enhancements will be made to integrate their databases and combine their data, to the degree desired. This work is expected to be appropriate for performance by the Systems Engineer and CTI, perhaps with occasional support from external consultants. The following main tasks are representative of the scope of work associated with this effort:

1) Identify IVHS components that would benefit from fused data, and determine their information needs (CDOT/CSP/Systems Engineer).

2) Select source systems for data fusion applications (CDOT/CSP/Systems Engineer).

3) Define desired end format for fused data (CDOT/Systems Engineer).

4) Define parameters for data fusion, e.g., reliability, longevity, automatic default input, etc. (Systems Engineer/CTI).

5) Develop data fusion operating software (CTI).

6) Implement software and hardware interfaces (Systems Engineer/CTI).

7) Data fusion trials and refinement (Systems Engineer/CTI.

8) Operational implementation of data fusion (Systems Engineer).

Within the development of the TOC's integrated database system, me potential also exists for public-private partnerships, particularly where these will support private ATIS efforts. private sector firms, with CDOT's guidance, may wish to develop data fusion software for the TOC at their own expense to provide a foundation for their ATIS initiatives. Integrated data fusion software packages of this nature will be particularly important in areas such as calculation of link travel times and analysis of congestion levels for their commercial ATIS devices. In a more conventional manner, private sector firms specializing in systems/software engineering could be awarded contracts to support integration and data fusion of the TOC's system databases.

Project Schedule and Cost

The project approach presented above has outlined a series of representative tasks to advance the TOC's single, reliable and integrated database system through to full implementation and operation. However, it is anticipated that numerous system databases will ultimately be included in fusion processes at the TOC. The level of complexity of each system's integration and fusion will vary.

Therefore, due to this activity's variability, a lump sum per annum budgeting approach is recommended. It is proposed that CDOT set aside $160,000 per year for a three-year period to cover the development and implementation of data fusion systems. This would begin in the medium term, when the TOC database integration efforts will be well underway.

Project Funding

Funding for this project will be required to support the input of CTI, plus any consultant support used. CDOT is expected to be the partner responsible for seeking funding support for this project. A combination of state funds and federal funds is likely to be used.

MAINTENANCE FLEET MANAGEMENT SYSTEMS

Objective

This activity will focus on the development and implementation of an integrated maintenance fleet management system for use in the Denver metro area. The key objective of this activity will be to manage the use of maintenance resources efficiently, particularly during extreme weather conditions when maintenance vehicles are required to keep the highway network operational.

The initial phase of this activity will assess the available weather monitoring and forecasting technologies, such as thermal mapping and ice detection systems, and select the most promising for use with fleet management systems. A subsequent phase will define a computerized dispatch system using specially-designed operations control software. This dispatch system will also be integrated with a communications system to determine vehicle location and facilitate the optimized scheduling. Following this preliminary design work, an operational test will be established using regular and emergency CDOT maintenance vehicles to assess this system's efficiency and utility.

Priority

Winter storms can have a severe impact on the Denver area highway system. Maintenance activities play a critical role in keeping highways open and helping the system to recover after harsh weather. Maintenance resources also undertake highway repairs and other activities to ensure continued mobility in the Denver area.

The system developed in this activity will aim to improve the performance of maintenance operations, while reducing costs through improved efficiency. The maintenance fleet management system will use local environmental sensor inputs, weather forecasts and maintenance work schedules to allocate vehicles effectively. This activity's dispatch system will determine vehicle location and facilitate optimized scheduling at all times, particularly during extreme weather conditions when maintenance vehicles are required to keep the Denver metro area freeway system operational. As this activity represents an advanced IVHS feature, it has been included for implementation during the medium-term timeframe.

Applicable IVHS Goals

This activity will primarily address the Denver area IVHS goals which follow:

- Increase transportation safety.
- Provide opportunities for academic research and private sector participation.
- Establish Colorado as a technology leader.
- Minimize new construction/maintenance costs.

- Reduce weather-related disruptions.

Activity Interrelationships

The establishment of the Denver TOC is again very important to this activity since it will provide a focal point for the metro area's maintenance communication and dispatch efforts. In addition, the maintenance fleet management system will include links with available environmental sensor systems and weather monitoring and forecasting technologies, through interfaces with databases housed within the Denver TOC.

In addition, other potential activities are interdependent with this activity. These include:

- TOC database integration.
- Data fusion.
- TOC expert system.
- Public and private dispatch systems.
- Emergency service dispatching and routing.

Approach

This activity will develop and implement an integrated maintenance fleet management system for the Denver metro area highway network. This system will include links to environmental sensors and weather monitoring systems. CDOT currently operates maintenance resources and weather-related facilities, and is therefore seen as the appropriate agency for management of this effort.

It is anticipated that maintenance dispatching in this activity will be integrated with a communications system to determine vehicle location and facilitate the optimized scheduling. In this area, opportunities for increased cost-efficiency through integration with CSP and RTD facilities (such as CSP's digital trunked radio and RTD's GPS) should be considered.

The potential for use of AVL should be investigated in the project. It is unlikely that an AVL system for exclusive use by maintenance vehicles would be affordable. However, it may be possible to achieve a cost-effective AVL solution by sharing some of the costs of an existing or proposed AVL system with other agencies such as CSP, RTD or the metro area's various city and county traffic departments.

Within the initial system design phases, it is anticipated that the majority of the work will be performed by CDOT personnel with consultant support. In establishing an operational test based on this design, a team would be formed to undertake the initiative. Potential members of this team include CDOT, other metro area agencies involved in maintenance efforts, RTD or CSP to facilitate joint use of AVL or dispatching facilities, and private sector firms providing environmental sensors and fleet dispatching and management software.

Scope of Work (SOW)

Development and implementation of maintenance fleet management systems will likely be undertaken in a phased approach as outlined above. Three phases will advance the program through an operational test, at which time a decision on widespread deployment can be made. The tasks listed below are representative of the scope of work associated with this effort.

Phase One:

1) Identify needs and requirements of metro area maintenance fleets (CDOT).

2) Assess the scope for cooperation with CSP, RTD and other metro area agencies (CDOT) .

3) Prepare an inventory of current environmental sensor equipment and weather monitoring facilities in the Denver metro area (CDOT).

4) Identify desired maintenance fleet management system functions (CDOT).

5) Develop procurement documents, request proposals, and select design consultant (CDOT).

Phase Two:

6) Once selected, the consultant will address the following design tasks:

- Assess the applicability of available weather monitoring and forecasting technologies and metro area communications systems.
- Evaluate the operating systems' overall hardware and software needs to meet CDOT's specified functionality.
- Identify additional equipment needed to complement existing systems.
- Prepare functional specifications for system monitoring, computerized dispatch operations control software, and in-vehicle components.
- Investigate the potential for AVL applications within the maintenance fleet management system.
- Prepare design documents and plans for an integrated maintenance fleet management system in the Denver metro area.
- Prepare operational test recommendations including project scope and potential participants.

Phase Three:

7) Review and refine system design and operational test plans (CDOT).

8) Assemble operational test team (CDOT).

9) Finalize operational test proposal based on Phase Two recommendations (Team/consultant).

10) Solicit federal funding support (CDOT/Team).

11) Maintenance fleet management system implementation, including software development and hardware deployment (Team).

12) System evaluation (Team).

Project Schedule and Cost

The project approach presented above has outlined a series of tasks that will advance this activity through to an operational test. These are divided into three main phases with corresponding schedule and cost estimates, as follows:

	Duration	Cost
1) Phase One: CDOT preparatory work	4 months	$30,000
2) Phase Two: system design and recommendations	10 months	$350,000
3) Phase Three: trial system deployment and operational test	14 months	$750,000
	28 months	$1,130,000

Work for this activity could begin in the short term, but probably should not be brought forward from Phase One until completion of the TOC. This will allow the effort to build on the availability of the TOC and other dispatching efforts in the metro area.

Project Funding

CDOT's lead role in this activity will also dictate that they he the partner responsible for seeking funding support. A significant proportion of the effort is likely to be state funded through the input of CDOT employees. CDOT could also fund the Phase Two consultant design contract, or could alternatively seek federal assistance.

The third phase is potentially appropriate for FHWA operational test funding. This would require a contribution by the project team to accompany federal input. This contribution could he derived, in part, through the involvement of CDOT or other public agency employees. Private sector firms, such as systems integrators and software developers, may also be prepared to offer some in-kind contributions to this effort.

Objective #4
Improve Incident Detection and Response

Activities

Incident Detection and Management

Develop Cooperative Exchange System
With TV and Radio Traffic Information Services

Public and Private Dispatch Systems

Pre-Planned Incident Diversion Routes

Emergency Service Dispatch and Routing

INCIDENT DETECTION AND MANAGEMENT

Objective

This activity will implement a thorough incident management program in the Denver metro area. Incident management is the coordinated, preplanned use of human, institutional, and mechanical resources to reduce the duration, impact, and congestion resulting from incidents on the road network.

At this time, the CIMC is actively pursuing opportunities in the area of incident management programs. The group published a recommendations report in September, 1992. Therefore, it is anticipated that this activity will be based substantially on the findings and recommendations of the CIMC.

In addressing this issue, the CIMC developed a number of goals and objectives for incident management in the Denver area (Reference 6).They include the following:

- Maintain and support an incident management program.
- Secure public cooperation in the implementation of incident management activities.
- Increase operational efficiency of incident management efforts.
- Minimize traffic delays on the roadway system.
- Reduce incident detection and verification time.
- Reduce agency response time.
- Reduce incident clearance time.
- Develop effective incident scene management.
- Provide timely and accurate information to motorists.

Initial efforts will focus on the Denver area freeway system, where the impacts of incidents are most severe. However, the practicality of extending an incident management program to the major arterials can also be assessed as part of continuing expansion efforts.

Priority

This activity has an important role to play in the implementation of IVHS in the Denver area. Lane closures due to traffic incidents are a major source of freeway congestion. Significant benefits, in terms of reduced vehicle hours of delay, fuel consumption, user costs, and secondary accidents can be realized by an effective incident management Program.

In addition, this activity has the potential to increase multi-agency and interjurisdictional cooperation within the Denver region. Since this activity will operate within the public's

view, it is also anticipated that a successful incident management program will encourage public support for IVHS. Due to the overall importance of this activity, it has be-en included within the scope of the Early Action Plan.

Applicable IVHS Goals

This activity will primarily address the IVHS goals which follow:

- Reduce congestion/improve mobility.
- Increase transportation safety.
- Minimize effects of incidents.
- Demonstrate interagency cooperation.
- Reduce potential hazardous impacts.
- Reduce weather-related disruptions.

Activity Interrelationships

The establishment of the Denver TOC will provide an invaluable resource for the incident management program - a coordination center. At the TOC, data from various locations, sources, and agencies will be gathered by computer and reviewed by trained personnel to form a wide-area picture of events as they occur. The TOC then becomes a support center for the incident response and clearance activities, and a focal point for the dissemination of traveler information. In essense, therefore, the long-term success of incident management efforts will be significantly increased by the existence of the TOC facility.

Implementation of the following activities will also significantly enhance the Denver area's incident management capabilities:

- Collection of real-time traffic volume and speed information.
- Expanded freeway ramp metering.
- Create temporary communications to key locations.
- Develop permanent communications network.
- Public and private dispatch systems.

In addition, other potential activities are interdependent with this activity. They include:

- Preplanned incident diversion routes.
- TOC database integration.
- Develop cooperative exchange system with television and radio traffic information services.

- Dial-in data collection system.
- Disseminate travel information region-wide (e.g., HAR, VMS, RDS, videotex, audiotex, etc.).

Finally, the following activities will be significantly enhanced by the implementation of incident detection and management initiatives:

- Maintenance fleet management system.
- Emergency service dispatching and routing.

Approach

To provide a coordinated approach to incident management in the Denver area, CDOT, in cooperation with the National Incident Management Coalition, sponsored the creation of the CIMC. This is a multi-agency, multi-disciplinary group representing a wide variety of public agencies and private corporations involved within incident management efforts. Initial CIMC recommendations identify over 26 actions which should be taken in the next few years to improve Denver's incident management program.

The continuing work of the CIMC will be to encourage the implementation of its recommendations and to periodically assess the benefits derived through this implementation. Additionally, the CIMC will identify new approaches and systems which can improve upon the manner in which incidents are managed. Most importantly, the CIMC will continue to foster interagency and interjurisdictional communications to assure public-private cooperation in addressing incident management in the Denver area.

Given the need to continue to address incident management issues among jurisdictions, the CIMC should remain intact and meet on an as-needed basis. Due to its multi-jurisdictional nature, DRCOG should continue to take an active role within the CIMC. In addition, because local governments and special districts have direct responsibility for incident response, a commitment to incident management by these jurisdictions is also necessary.

Scope of Work (SOW)

The recommendations of the CIMC Task Force include actions that will reduce the impacts of incident-induced congestion through improved management of the roadway system. The CIMC's recommendations provide the foundation for continued efforts to manage incidents in the Denver metro area. The CIMC has placed primary emphasis on short-term actions which can be initiated immediately and commissioned within a relatively short time frame. However, the CIMC's recommendations also take into account the relationships which exist between short-term and long-term actions. Table A-l provides an outline of the CIMC's incident management recommendations and proposed implementation schedule.

Project Schedule and Cost

The CIMC's recommendations report has outlined a series of tasks that will advance this activity through to full program implementation and operation. The CIMC's initial estimates of both capital costs and implementation schedule for its incident management program recommendations are shown in Table A-2.

Table A-3 identifies the CIMC's annual estimated operating costs. These costs include staffing the interim TOC, the public information program, training, the cellular call-m system, operation of the courtesy patrol, and the costs of committed CDOT and DRCOG staff to administer the incident management program and conduct the CIMC.

Project Funding

Potential funding sources, as identified by the CIMC, for Denver's incident management program are shown in Table A-4. Many of these are federal funds, provided through the 1991 Intermodal Surface Transportation Efficiency Act (ISTEA). With this federal funding comes a requirement for a local match. State Highway Users Trust Funds are looked to as the source of the match for most of the federal support. State and local funds are also considered for labor intensive organization, coordination, education, and legislation activities.

Note:

Information presented within this activity description is based upon the CIMC's Recommendations Report published September, 1992. Tables and text have been reproduced from this document to ensure consistency between the CIMC effort and the overall Denver metro area IVHS Master Plan (Reference 6).

Recommendation/Time Frame	Short Term (1-2 years)	Medium Term (2-4 years)	Long Term (4+ years)
Traffice Operations Center			
Interim	X		
Permanent		X	
Public Information Program	X		
Provide Training	X		
Intejurisdictional Cooperation	X		
Organized Cellular Call-in	X		
Reference Marking System	X		
Expand the Detector Network		X	
Verification			
Improve existing methods	X		
Video cameras		X	
Clarify Jurisdictional Boundaries			
Consensus maps	X		
Annexation legislation		X	
Place of trial legislation		X	
Common Communication System	X		
Courtesy Patrol	X		
Corridor Management Teams	X		
Clear Roads Legislation	X		
Minor Accident Legislation		X	
Abandoned Vehicles Legislation		X	
Accident Sites			
Investigate		X	
Site Implementation			X
Total Station Equipment	X		
Incident Command System Legislation	X		
Traffic Diversion Routes	X		
Provision of Equipment		X	
Highway Advisory Radio	X		

Table A-l. CIMC's Incident Management Recommendations

(Source: CIMC Recommendations Report, September 1992)
(Reference 6)

Recommendation/Time Frame	Short Term (l-2 years)	Medium Term (3-4 years)	Long Term (4+ years)
Traffic Operations Center			
Interim	547,000		
Permanent			
Organized Cellular Call-in	$200,000		
Reference Marking System	100,000	100,000	
Expand Detector Network		1,000,000	1,000,000
Verification Video Cameras		600,000	400,000
Consensus Jurisdictional Maps	50,000		
Common Communication System	85,000		
Accident Investigation Sites			300,000
Total Station Equipment	91,000		
Highway Advisory Radio	50,000		
Total	$1,123,000	$1,700,000	$1,700,000

- Cost to be estimated through the Denver IVHS Study.

Table A-2. Estimated Capital Costs of CIMC's Incident Management Recommendations

(Source: CIMC Recommendations Report, September 1992)
(Reference 6)

Item	Cost
Interim Traffic Operations Center	$556,000
Public Information Program	100,000
Training	50,000
Organized Cellular Call-in	90,000
Courtesy Patrol Committed Staff	350,000
CDOT	100,000
DRCOG	100,000
TOTAL:	$1,346,000

Table A-3. The CIMC's Incident Management Annual Estimated Operating Costs

(Source: CIMC Recommendations Report, September 1992)
(Reference 6)

Activity	NHS	STP	CMAQ	IVHS	MCSAP	CDOT	CSP	Local	Pvt.
Interim Traffic Operations Center	X	X	X			X	X		X
Permanent TOC	X	X	X	X		X	X		X
Cellular Call-in	X	X				X			X
Reference Marking System	X					X			
Detector Network	x	x	x	x		X			
Verification Video Cameras	X	X	X	X		X			
Jurisdictional Maps								X	
Common Communication	X	X				X		X	
Accident Investigation Sites	X	X	X			X			
Total Station						X	X		
Highway Advisory Radio	X	X				X			
Public Information	X	X				X	X	X	X
Training					X	X	X	X	
Interjurisdictional Cooperation						X	X	X	
Existing Verification Improvements								X	X
Legislation						X		X	
Courtesy Patrol	X	X	X			X			X
Corridor Management Teams						X	X	X	
Traffic Diversion Routes						X		X	
Equipment						x	x	X	
Scene Safety						X		X	

NHS: National Highway System (federal)
STP: Surface Transportation Program (federal)
CMAQ: Congestion Mitigation/Air Quality (federal)
IVHS: Intelligent Vehicle Highway System (federal)
MCSAP: Motor Carrier Safety Assistance Program
CDOT: Colorado Department of Transportation
CSP: Colorado State Patrol
Local: Local Government
PvL: Private Sector

Table A-4. Potential Funding Sources for CIMC Recommendations

(Source: CIMC Recommendations Report, September 1992)
(Reference 6)

DEVELOP COOPERATIVE EXCHANGE SYSTEM WITH TELEVISION AND RADIO TRAFFIC INFORMATION SERVICES

Objective

This activity will focus on the development of a cooperative exchange system with television and radio traffic information services. The purpose of this system is to develop an interface to share relevant information between the Denver area TOC and all participating media agencies.

Currently, there are several radio and television stations which monitor morning and evening peak hour traffic conditions. In addition, an independent traffic information service broadcasts on a number of other media outlets. These media services monitor police broadcasts and deploy their own airplanes and helicopters to collect information on current traffic conditions. This information can be valuable to the operations of the TOC, particularly for incident verification where CCTV coverage is not available or inoperational.

In addition to benefiting TOC operators, this cooperative exchange system has the potential to serve as an important tool for the dissemination of travel information to the public. The interface will provide media agencies with information on operating conditions on the network under TOC surveillance and control that may otherwise be unavailable. In turn, this information will allow the media to advise motorists of incidents or unusual circumstances on the roadway network. The cooperative exchange program should therefore be attractive to TV and radio services, since it will allow them to provide assistance to their customers.

Priority

The implementation of this activity is important to the early success of the Denver area IVHS program. In the initial stages of the program, there will be few ATIS outlets for metro area traveler information. To address this, increased cooperation in data collection and reporting activities will provide a coordinated effort between the TOC and the media. This will serve to make more effective use of each party's resources while allowing them to dispense a comprehensive view of traffic conditions to the motoring public. In addition, this activity presents a number of opportunities for public-private partnerships. Due to the importance of this activity, it has been included for implementation within the scope of the Early Action Plan.

Applicable IVHS Goals

This activity will primarily address the Denver IVHS goals which follow:

- Reduce congestion/improve mobility.

- Minimize effects of incidents.
- Integrate existing operations and IVHS programs.
- Provide real-time travel information.
- Demonstrate interagency cooperation.
- Provide opportunities for private sector participation.

Activity Interrelationships

The establishment of the Denver TOC is central to this activity because it provides a unique opportunity for information sharing between the TOC and participating media organizations. The TOC has the potential to serve as an information clearinghouse, with data-sharing capabilities between it and the media, as well as being a center for the dissemination of information to the public.

In addition, prior implementation of several activities will support this element of the program, through providing data that can be exchanged with media information. Contributing activities include:

- Collection of real-time traffic volume and speed information.
- Expanded freeway ramp metering.
- Dial-in data collection systems.
- Develop permanent communications network.

Other potential activities are interdependent with the implementation of a cooperative exchange system with the media. These include:

- TOC database integration.
- Incident detection and management.
- Disseminate travel information region-wide (e.g., HAR, VMS, RDS, videotex, audiotex, etc.);

The following will be significantly enhanced by the implementation of this activity:

. Expand CCTV coverage area.
- Data fusion
- TOC expert system.

Approach

The data sharing and dissemination of traveler information associated with this activity will center around the Denver area TOC. This suggests that CDOT should be responsible for those elements of the activity that necessitate modifications or enhancements at the TOC.

CDOT's role will need to be complemented by those media agencies involved with the cooperative exchange system. This will require agreement between CDOT and the media agencies over the nature of the cooperation, covering data to be exchanged, restrictions on use of data, and other related issues. It should be noted that CDOT has already held initial meetings with local media outlets to discuss such a cooperative exchange system.

It is anticipated that cooperative data exchange between the TOC and the media will occur in two primary ways. First, radio and television reporting capabilities will be included in the TOC in a media room. These will allow media personnel to operate in the TOC, accessing data under the supervision of CDOT. Second, for media agencies that do have a physical presence in the TOC, communication links will be established. These will allow voice, digital or video data to be fed to the agencies when needed. Likewise, information collected by the media can be sent back to the TOC, as part of the sharing arrangement. Such media-provided data can be used to expand incident detection and verification, or fused with other information to provide more reliable databases.

It is anticipated that a number of agreements will be reached between CDOT and media agencies concerning cooperative data exchange. The nature of each sharing arrangement will differ, as will the level of effort and scope of work needed to put it in place. However, a generic scope of work associated with this activity is outlined below, reflecting the tasks associated with a single media agency working with CDOT:

1) Agree scope and conditions of data sharing arrangement (CDOT/media agency).

2) Develop necessary TOC software and interface systems (CDOT).

3) Develop necessary media software and interface systems (media agency).

4) Deploy communications links and implement operational data exchange (CDOT/media agency).

5) Update TOC databases and data fusion processes to accommodate media-supplied data (CDOT).

Project Schedule and Cost

The project approach presented above has outlined a series of generic tasks that will advance this activity through to full system implementation and operation for a single data sharing arrangement. However, it is anticipated that a number of cooperative exchange systems will be deployed associated with different media agencies. The level of

complexity of each system and the time at which it is required, will vary. These variations will then determine each system's individual project schedule and cost.

To accommodate this variability, a lump sum per annum budgeting approach is recommended. A cost of $175,000 per year for a two-year period is believed appropriate to cover this activity's scope of work. This level of funding would support activities at the TOC undertaken to permit the media interfaces, and would be complemented by input from the media agencies themselves. This would begin when the Denver TOC is established, however the initial and ongoing discussions between CDOT and various local media seem to indicate that Approach Activity 1 may already be underway.

Project Funding

The majority of the funding associated with this activity is expected to be derived from private sector sources. In particular, the media agencies which wish to use data links with the TOC would be expected to cover the costs associated with deployment and operation of those links. This could include funding for necessary interfaces within the TOC, depending upon the nature of the agreement between CDOT and the media agency.

Some state funding is believed to be necessary for this activity, accounting for the $175,000 per year figure presented above. This would cover CDOT efforts in negotiating cooperative data exchange agreements, as well as modifications and enhancements to the TOC to integrate media-supplied data. State funds are considered the most likely source for these tasks.

Some media groups will also be interested in receiving TOC data, without providing anything back to the facility. In these cases it may be appropriate to charge a subscription or user fee, particularly where the TOC-supplied data are to be used for profit.

PUBLIC AND PRIVATE DISPATCH SYSTEMS

Objective

This activity will provide an additional source of field information for incident detection and verification efforts. In particular, this activity would utilize the various public agency and private sector vehicle dispatch systems as data sources for this information. Exchanges between these base dispatching stations and the Denver area TOC have the potential to provide timely information that would otherwise be unavailable, resulting in improved incident response efforts.

Priority

Although this activity does not represent a primary data collection mechanism, it offers an inexpensive way to complement the main sources of information at the TOC. As the activity involves utilization of existing dispatch resources, it may be included for implementation during any of the planning timeframes. The utilization of public agency and private sector dispatch systems for incident detection and verification efforts can provide valuable support in this area. In addition, this activity provides the opportunity for various public-private partnerships. It is therefore seen as a good value-for-money activity.

Applicable IVHS Goals

This activity will primarily address the IVHS goals which follow:

- Minimize effects of incidents.
- Integrate existing operations with IVHS activities.
- Provide real-time travel information.
- Demonstrate interagency cooperation.
- Provide opportunities for private sector participation.

Activity Interrelationships

The establishment of the Denver area TOC will provide a focal point for the metro area's incident detection and verification efforts. Information exchanges between the public agency and private sector dispatch stations and the TOC will extend the number of data collection resources utilized in the field. The TOC will therefore benefit from this activity, while the metro area as a whole will benefit from the resulting improvements in incident management.

In addition, other potential activities are interdependent with this activity. These include:

- TOC database integration.

- Data fusion.
- Maintenance fleet management systems.
- Develop cooperative exchange system with television and radio traffic information services.
- Dial-in data collection system.

The following activities will be significantly enhanced by the use of public agency and private sector dispatch systems for data collection:

- Incident detection and management.
- Disseminate travel information region-wide.
- Emergency service dispatching and routing.

Approach

The efforts of this activity will focus on providing incident detection and verification information. Since CDOT and CSP will be the primary agencies responsible for Denver's incident management efforts, they are also expected to jointly lead this initiative.

In addition, the joint lead role of CDOT and CSP will be complemented by those agencies involved with the public agency and private sector dispatch systems used in the project. Public agency participation could include the numerous city and county public work department vehicle fleets, as well as the local police departments. Private sector participants could include delivery trucks, taxis, utility maintenance vehicles and rental agency shuttle vehicles. It is anticipated that the majority of the work will be performed by employees of CSP and CDOT and the participating public and private agencies.

Scope of Work (SOW)

This project will involve establishing agreements and procedures for the exchange of information between the TOC and the public and private dispatch systems. Within the TOC, this work is likely to be addressed by the Incident Management Engineer and the Media Liaison representatives. These positions will work with staff from the participating dispatch groups to implement data exchange programs. The following main tasks are representative of the scope of work associated with this effort:

1) Prepare outreach materials to support the establishment of data sharing arrangements (CDOT/CSP).

2) Identify and prioritize public agency and private sector dispatch systems applicable to TOC operations (CDOT/CSP).

3) Approach dispatch organizations and agree to data exchange activities (CDOT/CSP/ dispatch organizations).

4) For each application selected, CDOT, CSP and the appropriate public or private sector group will address the following tasks:

- Define responsibilities and procedures for the data exchange.
- Identify any associated hardware and software needs.
- Assess communications needs and the extent to which they are met or unmet, for data exchange between the dispatch system's operations and the TOC.
- Implement data exchange program.
- Adjust incident response procedures and TOC databases and systems to accommodate the new data.

Project Schedule and Cost

The project approach presented above has outlined a series of representative tasks that will advance the use of public agency and private sector dispatch systems in incident management through to full implementation and operation. It is anticipated that a number of public agencies and private sector organizations will ultimately take part in this effort. In most cases, however, the cost is not expected to be high. The majority of the work is likely to be undertaken by employees of CDOT, CSP and the participating public and private sector groups. Some funding will also be needed to support deployment of communications interfaces.

Overall, a funding level of $40,000 per year for a four-year period is estimated to cover this activity's work scope. This could begin after the TOC is commissioned. It may be possible to establish some arrangements with public agency or private sector dispatch systems at an earlier date, as input to the interim TOC.

Project Funding

The majority of the effort in this activity is associated with the work of employees of the participating agencies. Therefore, these agencies will fund most of the effort through payment of employee salaries.

Some additional funding will be needed to cover deployment of communications interfaces. These are expected to be obtained from state or federal sources allocated to support the establishment of the TOC.

PREPLANNED INCIDENT DIVERSION ROUTES

Objective

This activity will focus on the provision of IVHS support for traffic diversion routes for use when freeway lanes within the Denver area become blocked due to severe incidents. Preplanned incident diversion routes create an excellent opportunity for interjurisdictional cooperation among participating agencies, and are recommended by the CIMC. The diversion routes will be developed by the appropriate jurisdictional agencies or corridor management teams. Initial work in this area is already underway through the CIMC.

Diversion routes should be established in a manner that assures the participating agencies that all reasonable measures will be taken to minimize the adverse impacts of the diversion of traffic onto the local roadway system. The objective of these activities will be to use IVHS technologies along designated traffic diversion routes to ensure that this is the case. The project will examine various methods of interfacing the preplanned routes with IVHS elements, potentially including:

- Automatic traffic monitoring to determine when a freeway incident necessitates use of a preplanned diversion route.
- Automatic traffic monitoring to ensure the arterials used for the diversion can accommodate the additional traffic.
- Upgraded traffic signal equipment and communications to the involved local intersections.
- Adjustments to the signal timing and phasing plans.
- On-site incident management coordinated by the TOC (e.g., signs, cones, arrowboards, etc.).
- Timely alternate route recommendations from the TOC (e.g., VMS, HAR, teletext, media newscasts, etc.).

Priority

Implementation of this activity is of major importance to the overall success of the Denver IVHS program. Preplanned incident diversion routes can provide enormous benefits by reducing the potential for delays and secondary accidents in the event of a major incident. IVHS technologies have significant potential to support the efficient operation of such routes. In addition, this activity provides an excellent opportunity for interjurisdictional cooperation which should establish the foundation for further freeway and arterial coordination. Due to the overall importance of this activity and its recommendation by the CIMC, it has been included for implementation in the scope of the Early Action Plan.

Applicable IVHS Goals

This activity will primarily address the Denver IVHS goals which follow:

- Reduce congestion/improve mobility.
- Increase transportation safety.
- Minimize effects of incidents.
- Demonstrate interagency cooperation.
- Successfully cross interjurisdictional boundaries.

Activity Interrelationships

The establishment of the Denver area TOC is central to this activity because it provides the focal point for the metro area's ATMS, ATIS and incident management programs. The use of preplanned incident diversion routes would be greatly enhanced by the TOC, which could detect and verify the incident, recommend the appropriate alternate routes and set in motion the necessary traffic control strategies.

In addition, other activities which will provide IVHS support for preplanned incident diversion routes include:

- Collection of real-time traffic volume and speed information.
- Expand closed circuit television coverage.
- Expanded freeway ramp metering.
- Advanced arterial surveillance.
- TOC expert system.

Several other IVHS program elements will both contribute to and benefit from this preplanned diversion routing activity. These include:

- Incident detection and management.
- Disseminate travel information region-wide.
- Dynamic route guidance.
- Adaptive traffic control.

Approach

This activity concentrates on the use of arterial streets as traffic diversion routes in the event of major incidents on the Denver metro area freeway system. CDOT is presently developing a GIS-based computer program ,with graphics capability for mapping, that will select an alternate route for diversion of traffic given the parameters of the extent of the

road closure. Further work and the cooperation of local governments, DRCOG and corridor management teams will contribute to the identification of the preplanned traffic diversion routes. Initial work in these areas is already underway subsidiary to the formation of Corridor Management Teams through the CIMC.

The main focus of this activity is the identification and deployment of IVHS measures to support the use of preplanned incident diversion routes. This is different from the actual selection of the preplanned routes, which is not in itself an IVHS activity. Therefore, consideration of potential IVHS support measures will be undertaken after the mutes have been determined.

Since this activity focuses on the diversion of traffic from Denver's freeway system, CDOT could serve as the agency charged with overseeing the effort. CDOT's role would be matched by the appropriate local agencies responsible for the arterials along which the diversion route passes. Close working relationships between CDOT, city and county traffic departments and corridor management teams are a key requirement for such cooperation. The involvement of DRCOG in the effort should also be beneficial in implementing IVHS support measures for preplanned incident diversion routes.

It is anticipated that the majority of the work associated with the initial development of the diversion routes will be accomplished in-house by CDOT, DRCOG, and the appropriate local agencies. The Corridor Management Teams being formed through the CIMC will continue to be a good forum for the initial coordination stages of this work. Identification of IVHS support measures will be more complex, probably requiring expert consultant assistance.

Scope of Work (SOW)

Implementation of preplanned incident diversion routes will reflect predefmed priorities established between the cooperating agencies. Once diversion routes have been identified, this activity will develop IVHS support measures to ensure their optimal operation. This could occur in a three-phase approach with consultant support. Phase One would develop designs for each diversion route, seeking to build on existing IVHS facilities to the maximum extent possible. Phase Two would implement the recommended measures and approaches to support a selected diversion route. Phase Three would then extend deployment to all of the diversion routes, in accordance with the results of Phase Two. Component activities for each of these phases are outlined below.

Phase One:

1) Identify agreed incident diversion routes (CDOT/DRCOG/Corridor Management Teams/local agencies).

2) Develop RFP for IVHS support, request proposals, and select consultant (CDOT/ DRCOG/local agencies).

3) For each diversion route selected, the consultant will address the following tasks:

- Identify existing IVHS and communications resources applicable to the temporary detour of traffic.
- Review additional technologies and approaches with potential to support automatic diversion routing.
- Identify methods to communicate diversion route strategies to the motoring public.
- Determine traffic signal control approaches (e.g., adjustments to the signal timing and phasing plans) to accommodate the additional traffic.
- Determine appropriate methods to implement new traffic signal control strategies for diverted freeway traffic (e.g., city or county control, traffic responsive operation, TOC control).
- Determine whether automatic computer implementation (expert systems) or personnel hands-on implementation with computer-generated advisories should be used.
- Determine functional requirements for associated software and hardware equipment needs.
- Assess communications needs and the extent to which they are met or unmet, within the diversion routing IVHS measures.
- Determine the criteria necessary to return the traffic signal control strategies back to normal operation.
- Prepare design documents, integrated systems architecture, hierarchical control strategies and associated materials for the deployment of IVHS measures to support diversion routes in the Denver metro area.
- Recommend a diversion route(s) for trial deployment.

Phase Two:

4) Review and refine system design (CDOT/DRCOG/local agencies).

5) Select diversion route for trial deployment of IVHS support measures (CDOT/ DRCOG/local agencies).

6) Software development (consultant).

7) Hardware and software deployment and integration (CDOT/consultant).

8) System evaluation (CDOT/DRCOG/local agency).

Phase Three:

9) Refine system architecture and operational procedures and functions, as required (CDOT/DRCOG/local agencies).

10) Widespread system deployment (CDOT/local agencies).

If the approach outlined above is adopted, approval to move into either of Phases Two or Three would be dependent on the demonstrated success of the activity in the preceding phase.

Project Schedule and Cost

Cost and time requirements for this activity can be assessed on a phase-by-phase basis, in accordance with the approach outlined above. Estimates for each phase are provided below.

The Phase One effort, involving review of technologies and preparation of system designs, has an estimated cost of $250,000. This could begin almost immediately, following selection of the preplanned incident diversion routes. The duration of this phase is estimated at ten months.

Phase Two, trial deployment and evaluation, would begin after successful completion of the design phase. The cost of Phase Two is estimated at $250,000, with a duration estimate of six months.

Phase Three, metro-wide deployment, would be dependent on the results of the Phase Two evaluation. If approved, this phase would implement IVHS support measures for several additional diversion route corridors. The cost of this phase will reflect the type of equipment selected for implementation, and the number of corridors served. An initial assessment of cost estimates expenditure of $300,000 per year over a three-year period for this activity. During this phase, it is anticipated that different diversion routes will be served by common monitoring and control facilities at the TOC.

Project Funding

Funding for this activity should be sought through federal and state sources. Phases One and Two may be appropriate for FHWA funding through initiatives such as the IVHS IDEA program, the corridors program or the operational test program. Widespread deployment in Phase Three could apply for ISTEA funding set aside for congestion mitigation.

EMERGENCY SERVICE DISPATCHING AND ROUTING

Objective

This activity will focus on the development of a system to improve the efficiency of dispatching and routing for emergency service vehicles in the Denver area. Efforts within this activity should be closely coordinated with the metro area's incident management initiatives, CDOT's maintenance fleet management system and the work of the CIMC.

The emergency service dispatching and routing system is envisioned as using dynamic map displays inside emergency vehicles to provide optimum routes to their destinations. This will include consideration of real-time traffic information available from the Denver area TOC or other distributed, jurisdictional facilities. In conjunction with the in-vehicle routing, modifications to traffic signals, for example through the integration of existing Opticom equipment, could potentially be made as required to facilitate rapid travel to the emergency scene. Potentially, an AVL element will be included which will enable the operator to review progress of the emergency vehicles, making adjustments where necessary.

Priority

This activity is seen as a follow-on to the earlier components of the Denver area IVHS Master Plan. It will use these initial elements and experience to introduce an advanced, life-saving emergency service support system.

Development of the area's emergency service dispatching and routing system will improve the efficiency of incident response efforts. The use of in-vehicle map displays, AVL, real-time traffic data and traffic signal adjustment will provide optimum routes to facilitate rapid travel to the emergency scene. As this activity represents an advanced IVHS feature, it has been included for potential implementation during the medium-term timeframe. However, some of the emergency service dispatching and routing system features may be realized in the short-term.

Applicable IVHS Goals

This activity will primarily address the Denver area IVHS goals which follow:

- Increase transportation safety.
- Minimize effects of incidents.
- Integrate existing operations with IVHS activities.
- Provide opportunities for academic research and private sector participation.
- Help establish Colorado as a high technology leader.
- Reduce environmental impacts from hazardous material spills.

Activity Interrelationships

The establishment of the Denver area TOC is very important to this activity since it will provide real-time traffic information for the metro area highway network. This information will facilitate the emergency vehicle's selection of an optimum route. The TOC also has the potential to become the focal point for operation of this emergency service dispatching and routing system, if integration of this nature is desired.

In addition, prior implementation of the following IVHS activities will significantly enhance this activity:

- Collection of real-time traffic volume and speed information.
- Expanded freeway ramp metering.
- CCTV coverage.
- Incident detection and management.
- Advanced arterial surveillance.
- Preplanned incident diversion routes.
- Data fusion.

The following activities can be approached interdependently with the implementation of an emergency dispatching and routing system:

- Maintenance fleet management systems.
- Dynamic route guidance.

Approach

This activity focuses on the development of a dispatching and routing system for emergency service vehicles. It is anticipated that, initially, city and county fire departments, paramedic crews, ambulance services and hazardous material forces will comprise the majority of the system users. CSP, city and county police departments and the corridor courtesy patrols may also benefit from the system.

This activity has the potential to include many different public and private agencies across numerous jurisdictional borders. It therefore will need close cooperation and coordination between these participating agencies. This indicates that DRCOG would be an appropriate group to foster this type of collaboration and oversee this effort. This appropriate expertise of DRCOG is illustrated by its leadership role in the CIMC and by its current regional traffic signal system improvement program to improve traffic signal coordination across jurisdictional boundaries.

Since the in-vehicle routing application of this activity will utilize real-time traffic information from the Denver TOC, CDOT and the other agencies which operate this

facility will need to be involved at a high level of participation. Opportunities for integration of existing Opticom or other equipment to make modifications to traffic signal operations will need authorization from the controlling agency to proceed. DRCOG's involvement should prove extremely beneficial in facilitating progress in these areas.

Due to the innovative nature of this project, it is seen as an appropriate project for an FHWA-sponsored operational test. This would involve formation of a public-private partnership to undertake the project and evaluate the system.

Scope of Work (SOW)

The following main tasks are representative of the scope of work associated with this effort:

1) Identify local emergency service dispatching and routing system project participants (DRCOG).

2) Identify private sector partners for participation in the operational test (DRCOG).

3) The project team, through a series of working groups, will define the scope of the operational test, including the following tasks:

- Review available technologies (e.g., in-vehicle map displays, route guidance systems, AVL, Opticom equipment, etc.) applicable to the system.
- Confirm needs to be addressed by the system.
- Determine functional and performance requirements for the system.
- Identify hardware and software development needs.
- Define scope of operational test implementation and nature of the evaluation.

4) Develop operational test proposal and solicit federal funding support (project team).

5) Hardware and software development and integration (private sector partners).

6) System implementation and operational evaluation (project team).

If the operational test proves the system a success, it may be expected to enter full service in the metro area shortly after completion of the project. Responsibility for this implementation would lie in part with the individual emergency services interested in using the system. CDOT or CSP would likely be responsible for installing the TOC database equipment required to support system operations. DRCOG could support the overall coordination of the full-scale deployment effort.

Project Schedule and Cost

The project approach presented above has outlined a series of tasks that will advance this activity through to readiness for full system implementation. These can be grouped into four main areas with corresponding schedule and cost estimates, as follows:

	Duration	cost
1) Project team formation (SOW Tasks l-2)	4 months	$30,000
2) System definition and proposal preparation (SOW Tasks 3-4)	8 months	$200,000
3) System development and integration (SOW Task 5)	8 months	$400,000
4) Implementation and operational evaluation (SOW Task 6)	12 months	$1,000,000
	TOTAL: 32 months	$1,630,000

It is anticipated that work on this project could get underway in the medium term.

Project Funding

As discussed previously, this project would to be appropriate for consideration as an FHWA-supported operational test. This provides the potential for partial federal funding. However, this must be accompanied by a local hard match It is expected that this match will be drawn from contributions from CDOT and other local participating agencies, as well as private sector firms which have an interest in developing a commercial product. As project coordinator, DRCOG would take the lead in securing the necessary funding commitments from involved partners, prior to submitting a proposal to FHWA.

Objective #5
Create a Region-Wide IVHS System Communications Network

Activities

Create Temporary Communications to Key Locations

Develop Permanent Communications Network

CREATE TEMPORARY COIMMUNI CATIONS TO KEY LOCATIONS

Objective

This activity will focus on the design and installation of a temporary communications network in the Denver area. This temporary network will support data collection and exchange in the early stages of the Denver IVHS program. It will connect the interim TOC, and subsequently the permanent TOC, to key locations, which could include information collection stations, traveler dissemination points and other agencies' databases.

Existing communications facilities in the Denver metro area are limited. Currently, communications for the ramp metering system include dedicated cable buried along the freeway and telephone line connections from key controller cabinets to the control computer located at CDOT Region 6. The North I-25 Corridor project includes a conduit and fiber optic communications backbone. This activity will investigate a variety of technologies and approaches which could supplement these available communications capabilities, as well as identifying appropriate locations for nodes in the network. The primary objective will be to satisfy critical IVHS data transfer needs during the period preceding deployment of a permanent communications network.

Priority

This activity is of major importance to the early success of M-IS in the Denver area. The creation of a temporary communications network will integrate existing communications media with new communications capabilities. Several of the program's initial IVHS efforts will rely on this temporary network before the permanent communications system is deployed.

This activity will also provide the infrastructure backbone from which a permanent communications network will be developed. Due to the overall importance of this activity, it has been included for implementation within the scope of the Early Action Plan.

Applicable IVHS Goals

Through its support for initial IVHS measures, the creation of a temporary communications network will address the Denver IVHS goals which follow:

- Reduce traffic congestion.
- Increase transportation safety.
- Minimize the effects of incidents.
- Integrate existing operations with IVHS activities.
- Demonstrate interagency cooperation.

Activity Interrelationships

The temporary communications network will provide valuable support to both the interim TOC and the permanent TOC. The network will transport data to the TOC from various sensors, field controllers and external agencies. It will also carry information, instructions and advice back from the TOC to these locations.

In addition, other potential activities will benefit from the temporary communications network in the short to medium term. These include:

- Collection of real-time traffic volume and speed information.
- Expanded freeway ramp metering.
- Develop permanent communications network.
- Incident detection and management.
- Develop cooperative exchange system with TV and radio traffic information services.
- Expand closed circuit television
- Disseminate travel information region-wide.

Approach

This activity will focus on providing communications facilities necessary to support initial IVHS elements in the Denver area. Many existing and potential activities will rely on this network to complete their information transactions. CDOT will be the lead agency for the majority of these activities, and therefore should also be responsible for managing this communications effort. CDOT is expected to draw significant support from the Division of Telecommunications in this work. Provision of communications components of the temporary network will most likely be achieved through contracts with telecommunications suppliers in the metro area.

Scope of Work (SOW)

Tasks within this activity need to be closely coordinated with other IVHS projects, particularly ATMS, ATIS and incident management efforts. The following main tasks will be included in the scope of work:

1) Prepare an inventory of current communications capabilities, equipment and locations in the Denver metro area (Telecommunications).

2) Identify IVHS activities requiring communications support prior to permanent network deployment (CDOT).

3) Evaluate the Denver metro area's additional communications needs (CDOT/ Telecommunications).

4) Develop bid documents, advertise requirements and select telecommunications suppliers (CDOT/Telecommunications).

5) Deployment of communications facilities to create the temporary communications network (various suppliers).

It is anticipated that the temporary network will integrate a number of communications media, potentially including leased telephone lines, limited fiber optic connections and microwave or radio links. These could be provided by a single telecommunications supplier, or alternatively through a combination of several firms providing system elements. Therefore, it is recommended that potential suppliers be requested to provide information on communications capabilities and costs for different components of the overall network. This will allow CDOT to select the best combination of offers to meet its specified needs.

Project Schedule and Costs

The project approach presented above has outlined a series of tasks that will advance this activity through to full system implementation and operation. It is anticipated that much of this activity's work will be completed as part of other individual ATMS, ATIS and incident management efforts. However, it is important that this activity act as the coordinating entity to fuse the individual components into a comprehensive structure.

The schedule for this activity will largely depend on the individual activities selected for early implementation. It is expected that deployment of the temporary communications network will occur in the short term (in conjunction with the development of the TOC), with a total cost estimate of $500,000 over this period. This cost is primarily associated with telecommunications supply contracts.

Project Funding

CDOT will be responsible for seeking funding support. Funding sources for this activity include federal funds and state funds.

As described previously, some elements of the temporary communications network may be deployed in conjunction with specific IVHS project activities. The funding sources used for these activities may therefore also be appropriate for the supporting communications systems.

DEVELOP PERMANENT COMMUNICATIONS NETWORK

Objective

This activity will involve the planning, design and implementation of a permanent communications network to integrate the various IVHS elements and activities deployed in the Denver metro area. This activity will build upon the foundation established during the creation of the temporary communications network and will potentially replace some of the interim communication links. From this initial communications infrastructure backbone, a permanent state-of-the-art communications network can be developed which will support the metro area's various needs and functions. The conceptual permanent network is illustrated in Figures A4 and A5.

The communications network is expected to reflect the use of fiber optic cables for most of its links. However, some alternative media may be used at selected locations, if this proves cost-efficient. The reader is referred to the "Communications System Conceptual Plan," prepared during this contract under separate cover, for additional information.

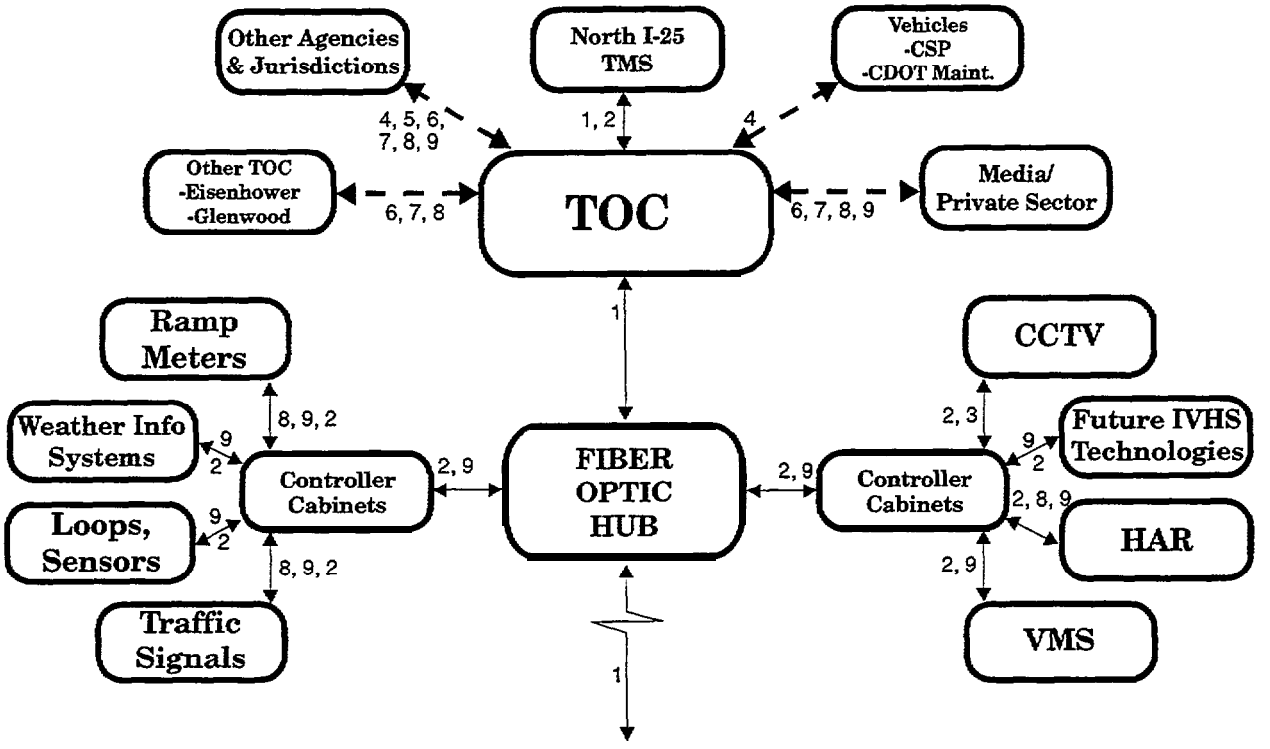
Priority

The development of a permanent communications network for the Denver metro area IVHS program is one of the most important activities to be included for implementation. A permanent communications network will provide the cornerstone for many of the planned IVHS functions and activities. If the TOC is considered the heart of the metro area's IVHS efforts, then the communications network represents the arteries which carry the critical flow of data around the system. Due to the overall importance of this activity, it has been included for implementation within the scope of the Early Action Plan. In addition, this activity will initiate implementation during the short-term timeframe while continuing to expand and enhance the network throughout the long-term timeframe.

Applicable IVHS Goals

Since the communications network will support a range of IVHS approaches in the Denver area, it is applicable to the majority of the program's key objectives. Specific goals that relate to the physical installation of the network include the following:

- Integrate existing operations with IVHS activities.
- Demonstrate interagency cooperation.
- Make use of existing, proven technologies.
- Successfully cross jurisdictional boundaries.
- Provide opportunities for private sector participation.



NOTE:
1. The controller cabinets do not necessarily support all of the field equipment shown. Each controller could support any number of IVHS components.
2. There are not necessarily 2 controller cabinets per fiber optic hub. There could be zero, one, two or more than
3. Controller cabinets can be located in the fiber optic hubs. Therefore, field elements can be brought directly to the hubs.
4. Fire optic hubs may only be present to relay the fiber optic signal (i.e. a given hub may not necessarily have any field equiment tied inwhatsoever).
5. The unspecified hard wire links shown will most likely be SMFO cable; however, other media may be more appropriate during the short term or as dictated by conditions encountered during final design.

LEGEND

1. SMFO Trunk System
2. SMFO Non-Trunk Connection
3. Coaxial Cable
4. Digital Trunked Radio
5. 800 MHz Radio
6. Fax
7. Microwave
8. Telephone (Cellular, Landline)
9. Unspecified Hard Wire Link

Figure A4 - Denver Area Conceptual IVHS Communications System

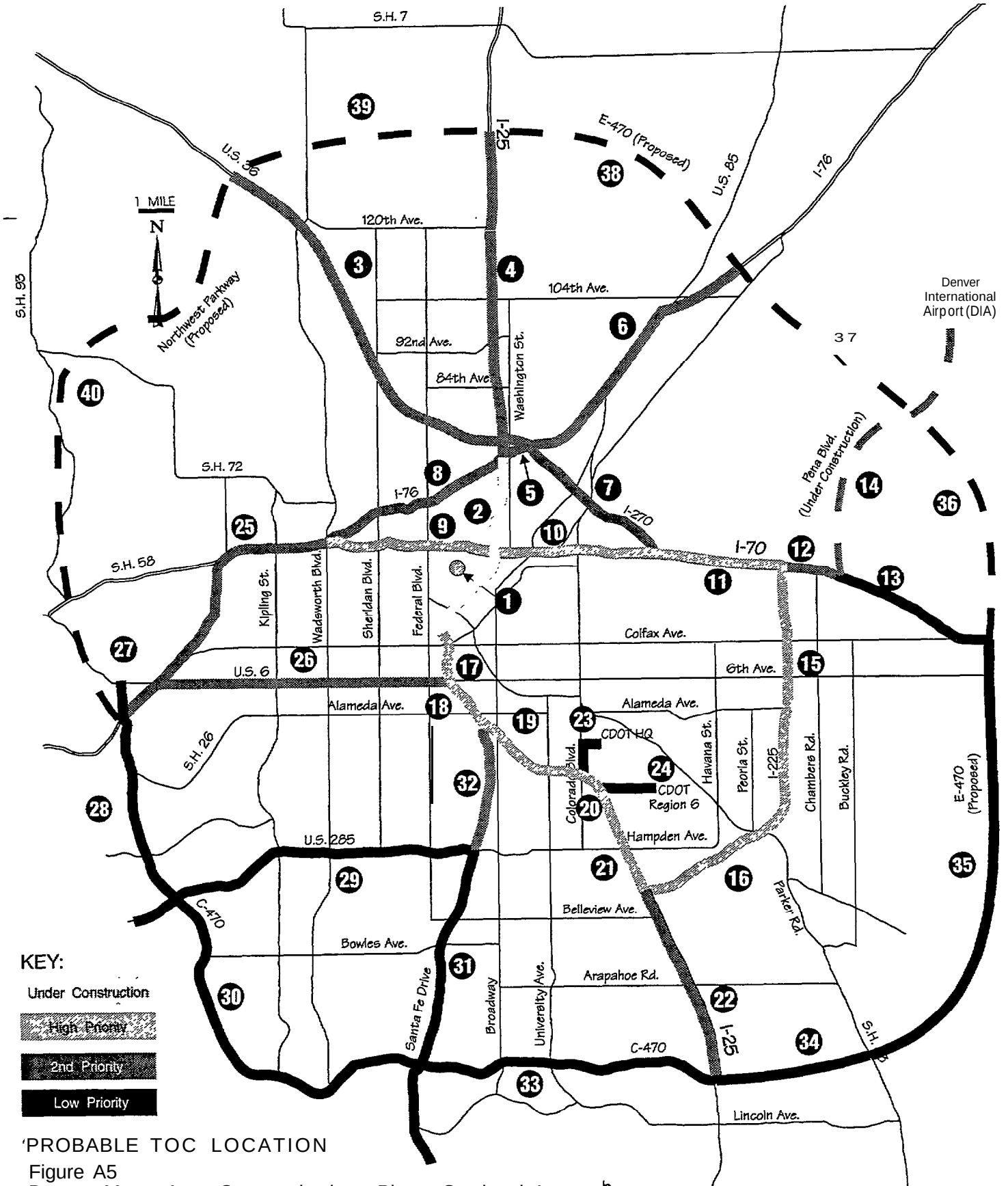


Figure A5
Denver Metro Area Communications Plan - Sectional Approach
Recommended Communication System Priorities

Activity Interrelationships

The establishment of the Denver area TOC is central to communications activities since it will provide a focal point for the IVHS technologies which make use of the communications network. The TOC will provide the physical facility for the permanent communications network's installation and hookup.

Several of the other IVHS initiatives will be dependent on the availability of a comprehensive communications network These include:

- Collection of real-time traffic volume and speed information.
- Expanded freeway ramp metering.
- Advanced arterial surveillance.
- Incident detection and management.
- Expanded CCTV coverage.
- Variable message signs.

Approach

This activity will focus on developing and providing the permanent communications network necessary to support the Denver IVHS program. Many existing and proposed technologies will use this network to complete their information transactions. Several of these systems are expected to be managed by CDOT. Therefore, CDOT is seen as the logical lead agency responsible for managing the effort, possibly with FKWA support. Input is also expected from other authorities in the Denver area, since the communications network should ultimately support operations in a number of jurisdictions.

This activity is particularly appropriate for a public-private partnership. It is anticipated that the first stage of the initiative would involve determination of communication needs by the local public authorities and private sector participants. This information would then be used as the basis for the preparation of bid documents. Unlike a traditional procurement, however, the solicitation would invite proposers to offer innovative, cost-sharing approaches toward network installation and operation. For example, a private company could offer to install the network at reduced cost to the state, in return for preferential access to the system's unused fibers. In addition, since trenching will comprise a majority of the overall cost, consideration should be given to the installation of additional conduit(s) for future vehicle-to-roadside communications, some of which may be led by private sector interests.

Scope of Work (SOW)

Tasks within this activity need to he closely coordinated with other ATMS, ATIS and incident management program components to ensure the overall success of the effort. The

following main tasks are representative of the scope of work associated with the communications network:

1) Prepare an inventory of current communications equipment and locations in the Denver metro area, including the temporary communications system (CDOT).

2) Determine functional communications needs, both current and future, in the Denver metro area (CDOT, with input from other local authorities and private sector participants).

3) Prepare guidelines for partial private sector ownership and use of the communications network (CDOT/FHWA).

4) Develop procurement documents, request proposals, and select supplier (CDOT).

5) Once selected, the supplier, with CDOT and the affiliated agencies, will address the following tasks:

   - Evaluate the Denver metro area's additional communications needs.
   - Identify and assess current locations which could be integrated within the Denver metro area's permanent communications network.
   - Review available technologies (e.g., leased telephone lines, fiber optic, microwave, spread spectrum radio) and multiplexing communications equipment.
   - Determine the permanent communications network's necessary quality, reliability, level of redundancy, compatibility, and expandability.
   - Determine the appropriate self-diagnostic features and maintenance support needs.

6) Prepare design documents, plans and an integrated systems architecture for the permanent communications network, and develop a proposal for joint public/private installation, ownership, and operation (supplier). Note that much of the initial architecture work has already been completed by CDOT in conjunction with the development of the North I-25 TMS.

7) Review the system design and finalize the public-private partnership (CDOT/FHWA/ affiliated agencies).

8) System implementation (supplier).

Project Schedule and Costs

The project approach presented above has outlined a series of tasks that will advance this activity through to full system implementation and operation. In reality, it is expected that some of this work will be completed as part of other individual ATMS, ATIS and incident

management efforts. However, it is important that this activity act as the coordinating entity to fuse the individual components into a comprehensive structure. Therefore, much of this activity's schedule and cost estimates will depend on the individual activities selected for implementation. Overall communications efforts can be grouped into five main areas with corresponding schedule and cost estimates, as follows:

	Duration	Cost
1) Communications network preparatory work (SOW Tasks l-2)	4 months	$50,000
2) Partnership guidelines and supplier selection (SOW Tasks 3-4)	6 months	$50,000
3) System analysis and design (SOW Tasks 5-6)	12 months	$500,000
4) Design review and partnership agreement (SOW Task 7)	6 months	$100,000
5) System implementation in high priority corridors (SOW Task 8)	50 months	* $36,100,000
	TOTAL: 78 months	$36,800,000

Represents high priority sections identified in 2nd draft of Communications Systems Conceptual Plan. Note that medium and long term sections identified in the plan required an additional $75.1 and $81.2 million, respectively.

It is anticipated that work for this activity could begin immediately. The temporary communications network should be in place during design of the permanent system.

Project Funding

CDOT will be the partner responsible for seeking funding support for this project. Funding sources for this activity include federal funds and state funds. In addition, other local agencies may be appropriate contributors to this activity. Their level of involvement and potential benefits will help to determine their financial responsibility.

As noted previously, this project appears well suited to implementation through a public-private partnership. Within the Denver metro area, there are a number of private sector companies which provide communications services. Joint construction and utilization of a fiber optic communications network could be an oppommity for CDOT to develop the systems more quickly and at lower cost to the public, and for a private company to utilize public right-of-way and unused fibers.

Objective #6
Diseminate Travel Information Region-Wide

Activities

Enhance HAR System

VMS Systems

RDS Broadcasting

Teletext and Cable TV Information Systems

Videotex Information Systems

Audiotex Information Systems

Dynamic Route Guidance

Electronic Signage

Automatic Speed Control

ENHANCE HIGHWAY ADVISORY RADIO (HAR)

Objective

This activity will focus on efforts to enhance current methods of broadcasting traffic information via HAR services in the Denver metro area. Currently, CDOT's HAR service is being used to broadcast recorded messages concerning activities such as construction work and road closures. In addition, much of CDOT's existing HAR is located in outlying areas to advise truckers and other interstate travelers of conditions in Denver. CDOT is investigating legalities and methods of extending the present HAR facilities into the urbanized portions of the freeway system. Figure A6 illustrates the existing HAR locations.

In order to improve the effectiveness of HAR, the following enhancements may be considered:

- Live audio traffic bulletins during peak periods.
- A continuous broadcasting option for use during major incidents.
- Roadside signs with flashing beacons to advise the motoring public to retune to the HAR service during live traffic broadcasts.
- Real-time traffic and weather information.

Priority

This activity is seen as a high priority, early component of IVHS implementation. HAR already provides CDOT with a proven, available method of traveler information dissemination. In addition, infrastructure for this service is currently in place in parts of the Denver metro area. Therefore, HAR enhancements can build directly and rapidly on the existing system. This will provide a valuable outlet for broadcasting data collected at the TOC, prior to the implementation of more advanced digital ATIS services. This HAR enhancement activity has been included within the scope of the Early Action Plan.

Applicable IVHS Goals

This activity will primarily address the Denver area IVHS goals which follow:

- Reduce congestion/improve mobility.
- Minimize effects of incidents.
- Integrate existing operations with IVHS activities.
- Provide real-time travel information.
- Reduce weather-related disruptions.
- Reduce potential hazardous impacts.

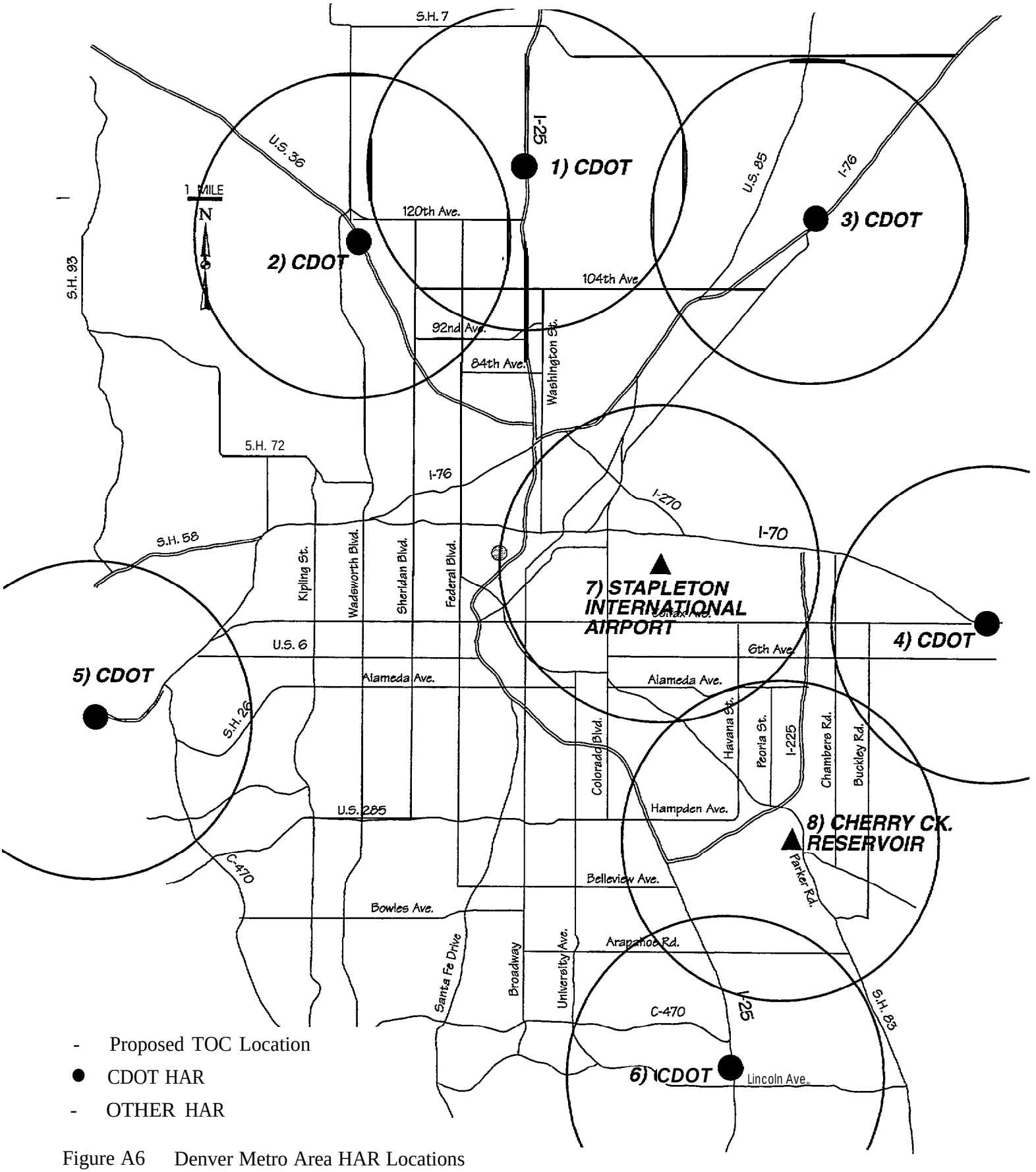


Figure A6 Denver Metro Area HAR Locations

Activity Interrelationships

Although HAR can operate independently, as demonstrated by its current use around Denver, the establishment of the Denver area TOC will be important in supporting enhancement of HAR operations. The TOC will provide a center for the collection of data for use in ATIS services, including, HAR. In addition, the ability of the TOC to act as a focal point for integration of various IVHS services will ensure that HAR use is combined with other technologies, such as VMS, to maximum effect.

Implementation of the Denver TOC will allow almost immediate improvements to these traveler information systems. With the TOC, incident notification will be significantly faster and the capability to change HAR messages much more convenient. HAR information will therefore be transmitted to the public in a more efficient and closer to real-time manner.

Implementation of the following initiatives will significantly enhance this activity:

- Collection of real-time traffic volume and speed information.
- Expanded freeway ramp metering system.
- Expand CCTV coverage.
- Incident detection and management.
- Dial-in data collection system.

Other IVHS program activities will be supported by the enhancement of HAR services. These include:

- Develop cooperative exchange with TV and radio traffic information services.
- Variable message signs.
- Preplanned incident diversion routes.

Approach

CDOT currently operates and maintains the existing HAR facilities around the Denver area freeway system, however CSP may operate the facilities when the interim TOC is implemented. However, CDOT is probably the appropriate lead agency responsible for HAR enhancement. It is anticipated that the majority of the work will be performed by CDOT personnel, with support from the State Division of Telecommunications. Some of the latter elements, concerning integration of HAR with TOC operations, will likely require consultant support.

Scope of Work (SOW)

The following main tasks are representative of the scope of work associated with this activity:

1) Resolve legal issues associated with new HAR deployment (CDOT/ Telecommunications).

2) Review current HAR capabilities, and identify appropriate locations and coverage areas for additional HAR (CDOT/Telecommunications).

3) Deploy new HAR equipment and initial telephone links for voice message recording (CDOT/Telecommunications/supplier).

4) Deploy HAR signing program and sign activating capabilities (CDOT/ Telecommunications).

5) Develop operational procedures for real-time message generation, verification and updating (CDOT/consultant).

6) Implement TOC connections and real-time HAR message generation (CDOT/consultant).

Project Schedule and Cost

The project approach presented above has outlined a series of tasks that will advance this activity through to full system implementation and operation. The CIMC has estimated that enhanced HAR system activities will cost approximately $50,000. This is believed to be sufficient to cover additional HAR equipment deployment. However, an increased investment will be needed to support introduction of real-time message capabilities. Expanded HAR system activities can be grouped into five main areas with corresponding schedule and cost estimates as follows:

	Duration	cost
1) CDOT/Telecommunications preparatory work (SOW Tasks l-2)	2 months	$10,000
2) New HAR deployment (SOW Task 3)	4 months	$40,000
3) HAR signing program (SOW Task 4)	3 months	$40,000
4) Develop real-time operational procedures (SOW Task 5)	6 months	$80,000
5) TOC interconnection and real-time operation (SOW Task 6)	6 months	$100,000
	TOTAL: 21 months	$270,000

Work on this activity can begin immediately.

Project Funding

CDOT will be responsible for seeking funding support for this project. Potential funding sources for this activity include federal funds and state funds. CDOT could also explore the concept of advertising or sponsorship of the HAR service as a means of funding this initiative.

VARIABLE MESSAGE SIGNS

Objective

This activity will involve evaluation and deployment of a variable message sign (VMS) system within the Denver area. VMS offers a valuable technique to provide motorists real-time traffic information and, if desired, alternate route selection advisories in advance of key decision points along the freeways. Currently, a VMS system is included in the design for the North I-25 Bus/HOV project. It is anticipated that this will be integrated into a broader, region-wide VMS network as the program continues.

Overall, VMS use should be integrated with other traveler information dissemination techniques. For example, CDOT could use portable VMS in conjunction with HAR in construction zones or other similar applications (Note that Region 6 already has several portable VMS which are currently used in the vicinity of major construction activities). CDOT should also continue to evaluate the need for additional VMS units in corridor-specific locations as communications capabilities are expanded.

Priority

This activity represents an important element of the ATIS component of the Denver area IVHS Master Plan. VMS can provide timely, accurate and reliable information to motorists when installed at critical locations. This can be achieved without the need for special, in-vehicle equipment. Thenfore, VMS is particularly valuable for the initial phases of the TOC operation. Due to the overall importance of this activity, it has been included for implementation within the scope of the Early Action Plan.

Applicable IVHS Goals

This activity will primarily address the Denver IVHS goals which follow:

- Reduce congestion/improve mobility.
- Increase transportation safety.
- Minimize effects of incidents.
- Make maximum use of existing, proven technologies.
- Provide teal-time travel information.

Activity Interrelationships

Implementation of the Denver area TOC is central to this activity since it will provide a focal point for the metro area's traveler information dissemination efforts. The TOC will be the physical facility from which the VMS system will be controlled. Within the TOC, operators will generate various messages for display on external VMS units.

Several additional activities will further enhance operation of the VMS system. These include:

- Collection of real-time traffic volume and speed information.
- Expanded freeway ramp metering system.
- Advanced arterial surveillance.
- Dial-in data collection system.
- Expand CCTV coverage.

The following activities are interdependent with VMS deployment:

- Enhance highway advisory radio.
- Incident management and detection.
- Preplanned incident diversion routes.

Approach

This activity will focus on the Denver area freeway system. Therefore, CDOT will be the lead agency responsible for managing the initiative. CDOT is also currently involved in efforts to implement VMS displays within the scope of the North I-25 Bus/HOV project. This will help to ensure coordination and consistency between these two efforts, ultimately integrating the I-25 facilities into the broader, region-wide network. It is anticipated that the majority of the work will be performed by private firms under contract to CDOT.

Scope of Work (SOW)

The following main tasks are representative of the scope of work associated with this activity:

1) Prepare an inventory of current VMS equipment and locations in the Denver area (CDOT).

2) Define scope of the VMS implementation effort, develop procurement documents, request proposals, and select consultant (CDOT).

3) Once selected, the consultant, with CDOT, will address the following tasks:

   - Evaluate the Denver area's additional VMS needs.
   - Identify and assess current locations to complete the Denver area freeway VMS system.
   - Review available technologies (e.g., flip disk, LED cluster, fiber optic, etc.) and information on their performance.

- Determine functional and performance requirements for the VMS equipment.
- Determine VMS software and hardware requirements for TOC database integration.
- Determine desired message generation capabilities and message display type.
- Prepare design documents, plans and specifications for the VMS equipment within the Denver metro area.

4) Review and refine system design (CDOT/consultant).

5) Develop bid documents, request proposals, and select equipment supplier (CDOT/ consultant).

6) System development and implementation (supplier).

Project Schedule and Cost

The project approach presented above has outlined a series of tasks for this activity. The CIMC has estimated a cost of around $1,000,000 for VMS deployment in the region. However, increased expenditure in this area would allow for expanded system coverage throughout the Denver area. The figures presented below are cost and schedule estimates for the VMS effort, divided into four main areas:

	Duration	cost
1) CDOT preparatory work (SOW Tasks l-2)	6 months	$50,000
2) Needs analysis, functional requirements and system design (SOW Task 3)	8 months	$300,000
3) Design review and supplier selection (SOW Tasks 4-5)	6 months	$50,000
4) System implementation (SOW Task 6)	16 months	$1,600,000
	TOTAL: 36 months	$2,000,000

This activity could begin in the short term and approach completion by the medium term. It is recognized that the actual implementation cost will reflect the VMS technology selected and the number of signs installed.

Project Funding

CDOT is expected to be the partner responsible for seeking funding support in this activity. A combination of federal and state funding is a potential method of support for VMS deployment in the region.

RADIO DATA SYSTEM BROADCASTING

Objective

This activity will focus on the implementation of a radio data system (RDS) broadcasting facility, or similar wireless digital communications service, in the Denver area. RDS is a subcarrier system which provides a silent data channel on existing FM radio programs, and has recently been approved as a North American broadcast standard. The objective of this activity will be to use this digital facility to provide an efficient way of conveying travel information to the public. In turn, this will support sensible route and mode choice, and avoidance of congested or hazardous areas.

RDS is, in fact, one of several communications media that could provide this type of service, with others including pager systems and SCA channels. The actual medium selected for the metro area should reflect the approach that offers the best combination of cost and performance. RDS has been chosen for this activity description primarily for purposes of illustration, and because it is already an existing, proven approach. Features of RDS, which could likely be replicated with other appropriate media, are outlined below:

- Traffic Program/Traffic Announcement (TP/TA). The TP feature is used by the RDS receiver to automatically identify radio programs which regularly provide traffic reports. The TA feature is then used by the RDS receiver to establish when traffic information is being broadcast. In combination, they allow the receiver to select a station which regularly broadcasts traffic information, and to increase the volume or mute a tape cassette during traffic announcements.

- Enhanced Other Networks (EON) Information. The EON information feature links a number of FM stations serving the same area. It can be used to monitor other stations offering the TA and TP facilities. By linking two or more of these stations with EON, the radio automatically scans these stations and can tune to whichever one is broadcasting traffic reports, subsequently retuning to the original station.

- Traffic Message Channel (TMC). The TMC conveys traffic messages in a digital format, through a data link to the FM broadcasting station, rather than simply identifying spoken messages. Traffic information messages generated at the TOC are coded into the TMC format using standardized lists of event messages and locations.

Priority

The implementation of a digital radio traffic information system is seen as a key ATIS element of IVHS in the Denver area. At a relatively simple level, such systems can identify stations that provide traffic updates, turn up the volume when a message is being broadcast, or retune the radio to receive the traffic message. These features help to increase the number of travelers that receive and act on the information. Even greater benefits may be realized through the implementation of fully digital traffic messages. More specifically, this approach

can convey a much larger volume of data than spoken messages, and the information can be recreated from its digital form in the language of the traveler's choice.

Applicable IVHS Goals

This activity will primarily address the Denver area IVHS goals which follow:

- Provide real-time travel information.
- Encourage private sector participation.
- Positively influence travelers' decision-making.
- Reduce congestion/improve mobility.
- Minimize effects of incidents.

Activity Interrelationships

The establishment of the Denver area TOC is seen as an important precursor to this activity, because it will serve as the traffic data collection focal point for the region. Traffic information will be coded into the appropriate digital format by a computerized message generating facility located at the TOC.

The operation of a digital radio service will also be supported significantly by the prior implementation of the following activities:

- Collection of real-time traffic volume and speed information.
- Expanded ramp metering system.
- Incident detection and management.
- Dial-in data collection system.
- Expanded CCTV coverage.

Other activities which are interdependent with the implementation of digital traveler information broadcasting include:

- Disseminate travel information region-wide.
- TOC database integration.
- Participation in standardization.
- Development of public-private partnerships.

Approach

CDOT is already participating in a national location coding effort for digital ATIS broadcasting through the ENTERPRISE program. Therefore, it seems logical that CDOT

should serve as the lead agency responsible for managing this effort. It is anticipated that most of the initial work in designing the system will be performed by consultant support to CDOT, although some tasks may be undertaken by CDOT personnel. System implementation and operation is expected to occur through a public-private partnership.

Scope of Work (SOW)

The following main tasks are representative of the scope of work associated with this effort:

1) Negotiate agreements with radio stations for participation in project (CDOT).

2) Prepare guidelines for operation of RDS-TMC in the metro area (CDOT/radio stations).

3) Develop procurement documents, bid contract and select consultant (CDOT/radio stations).

4) System design and software development (consultant).

5) Broadcast and message generating hardware procurement (CDOT/radio stations).

6) System implementation and commissioning (CDOT/radio stations/consultant).

7) Initial RDS trials (radio stations).

8) RDS-TMC trials (CDOT/radio stations/private sector partners).

9) Full-scale operation.

Project Schedule and Costs

The project approach presented above has outlined a series of tasks that will advance this activity through to full system implementation and operation. These can be grouped into five main areas with corresponding schedule and cost estimates, as follows:

		Duration	cost
1)	Radio station agreements and RDS-TMC operational guidelines (SOW Tasks l-2)	4 months	$50,000
2)	Select consultant (SOW Task 3)	4 months	$50,000
3)	System design and software development (SOW Task 4)	6 months	$200,000
4)	Hardware procurement and system implementation (SOW Tasks 5-6)	3 months	$100,000
5)	System trials (SOW Task 7-8)	4 months	$100,000
		TOTAL: 21 months	$500,000

It is anticipated that this activity could begin implementation late in the short term, following the commissioning of the TOC. Over the course of the program, full system implementation will occur when portable or in-vehicle TMC receivers are purchased by private consumers in the Denver area.

Project Funding

CDOT will be the partner responsible for seeking funding support. Potential funding sources for this activity include federal and state funds, as well as private sector contributions.

Private sector contributions are considered most likely in two areas. First, the partner radio stations are expected to take part in the project at no charge to the public, except perhaps the low cost of purchasing the RDS encoding equipment. This is because the radio stations can use the RDS feature as a marketing tool to increase audience size.

The second area of potential private sector contributions is provision of receiver units. It is expected that receiver manufacturers will be willing to provide units on loan for the initial system trials in the Denver area. Again, these firms will benefit from the exposure that this provides, plus the future commercial opportunities for sales of the product. Other areas that are considering similar projects have also received offers of test vehicle loans from supportive automobile manufacturers.

TELETEXT AND CABLE TELEVISION INFORMATION SYSTEMS

Objective

This activity will aim to design and implement a television-based traffic information service for the Denver area. Review of this information by travelers will be possible through a teletext service and a dedicated cable television channel.

The cable channel will present a color-coded speed map of the entire freeway system in a format suitable for relay into homes in the Denver area, as well as for display on terminals in downtown office buildings. In addition, the cable channel will include a picture insert window capable of broadcasting live images of major incidents from the proposed CCTV camera system. The teletext service will be interactive and will supplement the cable channel, offering a number of pages of traffic information, selectable by area or information type.

Priority

Implementation of a television-based traffic information service is seen as important to the overall success of the ATIS component of IVHS in the Denver area. This type of service will assist motorists significantly in their pretrip planning efforts, allowing them to make more informed choices. Due to the overall importance of this activity, as well as the proven state of the technology, it has been included for implementation within the scope of the Early Action Plan. The dedicated cable television channel could be implemented during the short-term timeframe. The teletext service could then be developed for this system in the medium-term timeframe.

Applicable IVHS Goals

This activity will primarily address the Denver area IVHS goals which follow:

- Influence travelers' decision-making.
- Reduce congestion/improve mobility.
- Make use of existing, proven technologies.
- Provide real-time travel information.
- Encourage private sector participation.

Activity Interrelationships

To make full use of television-based ATIS services, this activity relies on the establishment of the Denver area TOC. The television-based systems will use the information sources available at the TOC to compile traffic messages and generate

graphical images in real-time. This activity will also be capable of broadcasting live images from TOC-controlled CCTV cameras.

In addition, prior implementation of the following IVHS elements will significantly enhance this activity:

- Collection of real-time traffic volume and speed information.
- Expanded freeway ramp metering.
- Develop permanent communications network.
- Expand CCTV coverage area.

Other activities which can be approached in conjunction with the deployment of a television-based traffic information service include:

- Develop public-private partnerships.
- RDS broadcasting.

Approach

This activity relies on the Denver area TOC's traffic management and information dissemination activities. Since it seems likely that CDOT will manage these efforts, they should also be the agency responsible for overseeing this activity.

In particular, responsibility for coordinating this activity should be placed with the new Systems Engineer position within the TOC. This position would oversee the development of software and hardware systems which would enhance the information interface capabilities between the Denver area TOC and the television-based traffic information service.

In addition, CDOT's lead role will need to be complemented by the involvement of private sector companies to ensure the success of this activity. An agreement will be required with a local cable operator to provide television channel access. Private sector support will also be required in the teletext component of this activity, for marketing and distribution of the decoder units.

Scope of Work (SOW)

Implementation of this activity will likely be undertaken in a phased approach. The cable channel would be deployed initially with the supplementary teletext service developed shortly thereafter. The main tasks representative of the scope of work associated with this effort are outlined below.

Cable Television System:

1) Review available software and previous experience with presentation of graphical and CCTV images via cable TV (CDOT/Systems Engineer).

2) Determine optimal approach for metro area cable TV channel and undertake functional design (CDOT/Systems Engineer).

3) Negotiate agreement with local cable TV operator, and request proposals for system software development (CDOT/Systems Engineer).

4) Software development for the cable TV system (consultant).

5) System implementation, including links to the cable operator, and placement of TV terminals in selected public places (CDOT/Systems Engineer/cable operator).

Teletext System:

6) Identify private sector partner(s) for teletext system, and negotiate agreements with TV channels to carry teletext information (CDOT/Systems Engineer).

7) Teletext system functional design &DOT/Systems Engineer/private sector).

8) Software development for teletext database (private sector/Systems Engineer).

9) System implementation through establishment of communications links to participating TV broadcast stations (private sector/Systems Engineer).

In the development of the cable television and teletext information system, the potential exists for a number of public-private partnerships, particularly since these may support private ATIS efforts. With the cable television system, the provision of a traffic information channel provides a value-added service for customers. This should make it an attractive proposition for local cable operators, acting as an incentive for them to offer channel space and implement the needed communications links.

The teletext system should also be of interest to the private sector. Again, television stations should be attracted by the value-added service offered by teletext. More importantly, the implementation of a teletext service will open up markets for the manufacturers and suppliers of decoder equipment. This incentive could be used to leverage support from the private sector in undertaking software development for the teletext database, and subsequent system implementation.

Project Schedule and Cost

The project approach presented above has outlined a series of tasks that will advance this activity through to full system implementation and operation. These can be summarized with corresponding schedule and cost estimates, as follows:

	Duration	cost
1) Review and system design for cable TV service (SOW Tasks l-2)	4 months	$50,000
2) Cable TV negotiation and software supplier selection (SOW Task 3)	5 months	$50,000
3) Cable TV software development (SOW Task 4)	6 months	$100,000
4) Cable TV system implementation (SOW Task 5)	3 months	$50,000
5) Private sector partner negotiations and teletext functional design (SOW Tasks 6-7)	5 months	$100,000
6) Teletext software development (SOW Task 8)	6 months	$300,000
7) Teletext system implementation (SOW Task 9)	3 months	$50,000
TOTAL:	32 months	$700,000

It is anticipated that this activity could begin in the short term. Following full implementation of the teletext service, it will be the responsibility of the private sector to market and distribute receiver devices for use in the metro area.

Project Funding

This activity is expected to be funded largely by the private sector, particularly with regard to the teletext service. For the cable TV service, some support is anticipated from participating cable TV operators in establishing the necessary communications links. However, public funding will be required to get this project off the ground and cover the costs of input by CDOT and the Systems Engineer. This is likely to be drawn from state and federal sources.

In addition, ongoing funding support could be acquired through the sale of advertising space throughout the broadcasts or outright sponsorship by interested organizations. FHWA's regional office has indicated that a private firm has already made an approach to discuss cable television for traveler information in the Denver area.

VIDEOTEX INFORMATION SYSTEMS

Objective

This activity will implement an interactive traveler information service in the Denver area through a videotex system, based on the TOC's information databases. This service will offer traffic and traveler information, weather conditions, transit service enquiries and route planning facilities to the Denver area's residents.

A videotex system comprises a dedicated computer and video terminals linked to the TOC via telephone lines. The use of telephone lines to communicate with a central database provides a two-way link for the system, thereby offering an interactive service. Information will be available in a number of locations including private homes, office buildings, public activity centers, parking garages and gas stations.

RTD, CDOT, and Westinghouse Electric Corporation are currently initiating a similar demonstration project to provide real-time bus departure information on television monitors located at the Civic Center and Market Street Stations downtown, at several Park-n-Ride facilities, and at Denver International Airport. Future videotex projects should build upon these current efforts. This project has been approved by USDOT as an operational test project for IVHS.

Priority

An interactive videotex information system is seen as a valuable ATIS component of the Denver area IVHS program. This type of service will provide local residents a reliable source of pretrip traffic and traveler information at a number of strategic locations. Receipt of these data will allow travelers to make optimal decisions with regard to travel route, time and mode.

It is recognized that private sector initiatives may have already introduced commercial videotex services in the Denver area, during the short-term timeframe of the IVHS Master Plan (Reference the RTD/CDOT/Westinghouse project described above). Therefore, emphasis in this project will be placed on providing consistent travel data from the TOC through an interface with these systems. Concentrated efforts for this activity within the Denver area TOC are expected to get underway in the medium-term timeframe. However, if commercial services introduce videotex at an accelerated schedule, the ATIS function may also be deployed sooner.

Applicable IVHS Goals

This activity will primarily address the Denver area IVHS goals which follow:

- Provide real-time traveler information.
- Support/enhance transit operations.
- Provide opportunities for private sector participation.

- Reduce weather-related disruptions.
- Reduce congestion/improve mobility.

Activity Interrelationships

The establishment of the Denver area TOC is central to this activity because it provides the focal point for the metro area's real-tune information collection efforts. The interactive videotex information system will base its service provisions on the TOC's information database.

In addition, prior implementation of the following activities will significantly enhance this project:

- Collection of real-time traffic volume and speed information.
- Expanded freeway ramp metering.
- Incident detection and management.
- Expanded CCTV coverage.

Evaluation of the RTD/CDOT/Westinghouse demonstration project will also provide valuable input prior to implementing an expanded videotex system.

Other ATIS activities can be approached in parallel with the deployment of an interactive videotex information service. This will allow the different services to use common databases and ensure consistent dissemination of information. NHS program activities which can be pursued in conjunction with videotex include the following:

- Develop public-private partnerships.
- TOC database integration.
- Teletext and cable TV systems.
- Audiotex information systems.

Approach

The interactive videotex information services would rely heavily on information accessed from the TOC's databases. This suggests that CDOT should be the agency responsible for managing the provision of data for videotex dissemination. In particular, responsibility for coordinating this activity should be placed with the Systems Engineer in the TOC. This position would oversee the development of software and information interface capabilities between the interactive videotex service and the TOC.

In addition, CDOT's role will need to be complemented by the involvement of private sector companies to ensure the success of this activity as in the RTD/CDOT/Westinghouse demonstration project. Close coordination and cooperation will be necessary with those private firms which established commercial videotex services. An agreement will need

to be reached between CDOT and the videotex service supplier concerning issues including acceptable videotex user fees, use of the TOC-supplied data, and the service coverage area. Such an agreement should ensure that CDOT does not simply donate the TOC data, with no control over its subsequent use by the videotex provider.

Scope of Work (SOW)

Implementation of this activity will focus on coordinating the TOC's activities with commercial videotex systems. This will be undertaken as a joint effort of CDOT and the videotex service operator. The main tasks representative of the scope of work associated with this effort are outlined below:

1) Agree scope and conditions for the videotex traveler information service (CDOT/ videotex operator).
2) Software development for videotex data supply (CDOT).
3) Software development for menu functions and interactive ATIS features (videotex operator).
4) TOC/videotex interconnection and system operation (CDOT/videotex operator).

Project Schedule and Cost

The project approach above has outlined tasks associated with this videotex activity. These can be summarized with corresponding schedule and cost estimates, as follows:

	Duration	cost
1) Agreement of scope and conditions (SOW Task 1)	3 months	$25,000
2) Software development (SOW Tasks 2-3)	8 months	$300,000
3) Videotex system implementation (SOW Task 4)	3 months	$100,000
TOTAL:	14 months	$425,000

It is anticipated that this activity will begin in the medium term, by which time commercial videotex is expected to be operating with significant market penetration. However, the ATIS videotex function may be implemented sooner if commercial services are introduced more rapidly in Denver.

Project Funding

It is anticipated that much of the funding for this activity will be provided by the private sector, as videotex would be operated as a for-profit venture. The inclusion of an ATIS function would increase the utility of videotex, thus making it more attractive and marketable. Therefore, the videotex operator may be willing to provide funding for state activities needed to establish the ATIS component. This could match funds from state or federal sources.

AUDIOTEX INFORMATION SYSTEMS

Objective

This activity will introduce an audiotex service for transit users in the Denver area. The audiotex information system will provide transit users with real-time information on bus services and schedules via a touchtone telephone access system. This activity will build on RTD's current information services and will be enhanced by the implementation of the GPS system.

Following commissioning of the GPS service, an initial phase of this project will enhance the current transit enquiry facility. This will allow real-time information to be provided to customers with manual responses supported by computer data retrieval. Through a subsequent system enhancement, it is envisioned that a single telephone number will be introduced for the audiotex service. This will allow callers to use their telephone touchtone keys to move between menus and select the required transit information.

The objective of these efforts will be to improve the accuracy and accessibility of useful transit information, thus encouraging a greater proportion of metro area travelers to use transit,

Priority

The audiotex information system will serve as a valuable component within the region-wide information dissemination network. In particular, the activity will support multi-modal aspects of Denver's transportation system. Due to the potential benefit of providing accurate, real-time transit information, this activity has been included for implementation within the scope of the Early Action Plan. Initial steps are already being considered by RTD, building on deployment of the GPS system. This project could also take advantage of the real-time aspect of the RTD/CDOT/Westinghouse demonstration project described in the previous section

Applicable IVHS Goals

This activity will primarily address the Denver IVHS goals which follow:

- Support/enhance transit.
- Integrate existing operations with IVHS activities.
- Provide real-time travel information.
- Provide operational improvements through technology.

Activity Interrelationships

This activity will be enhanced by the establishment of the area Denver TOC. Although RTD would likely maintain and operate the audiotex service, the TOC will serve as the focal point for the overall traveler information databases in the metro area. The TOC will therefore provide data on highway conditions, weather and other issues which will be of use to RTD in operating the audiotex system.

In addition, other activities are interdependent with the implementation of an audiotex information system. These include:

- TOC database integration.
- Disseminate travel information region-wide.
- Interactive rideshare management and matching system.
- CDOT/RTD/DRCOG partnership.
- Public-private partnerships.

Approach

The audiotex information system will focus on the transit system operated by RTD. Therefore, RTD should serve as the lead agency overseeing this effort. The involvement of CDOT in the project will support integration of the audiotex service with other IVHS databases resident at the TOC.

RTD's transit fleet is currently undergoing implementation of a GPS system for fleet monitoring and management. RTD (in partnership with CDOT and Westinghouse) has already begun work on a real-time transit information service, supported by the GPS system. Therefore, it seems likely that the audiotex service could also be provided by the GPS supplier through a further contract extension.

Scope of Work (SOW)

The following main tasks are representative of the scope of work associated with this effort:

1) Negotiate scope of real-time, operator-provided information system (RTD/GPS supplier).

2) Software development for real-time information system (GPS supplier).

3) System implementation and integration with GPS capabilities (GPS supplier).

4) Operator training (GPS supplier/RTD).

5) Negotiate scope of audiotex service implementation (RTD/GPS supplier).

6) Agree upon exchange procedures and specify interfaces between the TOC and the audiotex service (RTD/GPS supplier/CDOT).

7) Define menu structure and message formats for audiotex service (GPS supplier/ RTD).

8) Audiotex software development (GPS supplier).

9) TOC interface deployment (RTD/CDOT).

10) Audiotex system implementation (GPS supplier).

Project Schedule and Cost

The approach outlined above can be divided into two primary phases. The first phase will develop and deploy a real-time information retrieval system to support operators' responses to transit users' enquiries. The second phase will build on this service in introducing a videotex system. Cost and duration estimates for these phases are outlined below.

RTD's efforts for a real-time transit information service (with CDOT and Westinghouse) will likely get underway in 1994, with completion in 1995. The cost of introducing the system and training RTD's telephone operators is estimated at $200,000.

The introduction of an audiotex service would follow and build on deployment of the real-time information retrieval system. It is anticipated that this initial service would be evaluated and refined over a period of several months before embarking on the audiotex initiative. Therefore, development of the audiotex system could occur at the earliest in the latter short term, with implementation thereafter. This would allow commissioning of the audiotex system to coincide with initial operation of the TOC. The cost of developing and deploying audiotex, including TOC interfaces, is estimated at $350,000.

Project Funding

This project will build on the ongoing deployment of GPS technology on RTD's transit fleet. This is a leading edge initiative which has received significant federal funding support. Similarly, deployment of a real-time information retrieval system, and subsequently an audiotex service, would further advance the state-of-the-art in the APTS arena. Therefore, FTA is seen as a promising source of financial assistance for implementation of this activity.

DYNAMIC ROUTE GUIDANCE

Objective

This activity will focus on the design and implementation of a dynamic route guidance system for the Denver metro area. This is expected to substantially build upon the major route guidance demonstrations currently underway in the United States--Orlando's TravTek, Chicago's ADVANCE and Los Angeles' Pathfinder. The results of each system's evaluation will provide the insight to determine the framework for a regional dynamic route guidance system. Technical considerations include the in-vehicle navigation system, communications system architecture and interface capabilities with the Denver area TOC.

Priority

The implementation of this activity is important in the Denver area's attempts to reduce congestion and improve mobility within the metro area. Dynamic route guidance systems offer the potential to optimize individual route planning applications--both pretrip and en route. In addition, in-vehicle systems can be used as traffic information collection sources or probes. It is anticipated that the metro area will utilize existing, proven technologies within its dynamic route guidance system. This implies that implementation of this activity will begin in the medium-tenn or long-term time frame, once the component technologies have reached maturity.

Applicable IVHS Goals

This activity will primarily address the Denver area M-IS goals which follow:

- Influence traveler's decision-making.
- Reduce congestion/improve mobility.
- Make use of existing, proven technologies.
- Provide real-time travel information.
- Encourage private sector participation.

Activity Interrelationships

The establishment of the Denver area TOC will greatly assist the deployment of a dynamic route guidance system in the metro area. The TOC will house the Denver area's information databases, including traffic conditions, weather, incidents and construction. The TOC will also contain the computer processing abilities to integrate and fuse the data into a meaningful format. The dynamic route guidance system will depend on the TOC to provide these real-time data as a basis for optimal route planning.

In addition, prior implementation of the following activities will significantly enhance the route guidance system deployment:

- Collection of real-time traffic volume and speed information.
- Expanded freeway ramp metering system.
- Incident detection and management.
- TOC database integration.

The following activities can be developed in conjunction with the dynamic route guidance system:

- TOC data fusion.
- TOC expert systems.

The operation of a dynamic mute guidance system also has the potential to contribute to long-term activities such as fourth generation signal control, through providing input to prediction of future traffic conditions.

Approach

This activity will implement a dynamic mute guidance system in the Denver area. Current demonstration projects in the United States (TravTek, ADVANCE and Pathfinder) contain various public-private partnerships. For example, the ADVANCE program has four principal parties--Illinois Department of Transportation (IDOT), FHWA, Motorola and the Illinois Universities Transportation Research Consortium (IUTRC)--as well as many other participants including automobile manufacturers, private consultants and computer firms. The potential exists to develop similar arrangements with parties local to the Denver metro area. However, the emphasis will be on full-time deployment rather than operational demonstration and evaluation.

The Denver area's dynamic route guidance system will rely on communications with the TOC for real-time traffic information. The TOC will play a pivotal and integral role within this activity due to its ability to collect, process and disseminate travel conditions to vehicles equipped with navigational units. Therefore, the TOC's likely managing authority, CDOT, should be the lead agency responsible for managing the effort. CDOT's lead role would be similar to the one currently provided by Illinois DOT within ADVANCE, involving provision of data needed for system operation.

Due to the nature of this project, it is anticipated that deployment and operation of route guidance system components outside of the TOC will best be undertaken by the private sector. This will allow the private sector to produce in-vehicle navigation devices in response to market forces. This recognizes that the individuals who choose to use and pay for the system will gain the most benefit. However, there will also be an overall network benefit, so that involvement of the state-operated TOC will be appropriate.

This approach toward mute guidance operation could be achieved through a proposal process. CDOT would identify the fundamental requirements of me system, and would then invite suppliers to propose alternatives for system installations. Responders would indicate

the functions that they could provide and the conditions under which deployment and operation would occur. In selecting a proposal, CDOT would essentially be granting permission for a commercial route guidance deployment using TOC data. Involvement of local industries could be made a requirement to foster a community spirit in achieving this activity's objectives.

When a system approach is selected, it is unlikely that the TOC will already be capable of producing data in the exact format required. This could be addressed by input from academic groups such as the Colorado Transportation Institute (CTI). CTI personnel could undertake software development for the dynamic route guidance system as well as provide technical input for additional system components. CTI's role would be similar to that of the IUTRC within ADVANCE.

Scope of Work (SOW)

Due to this activity's numerous partnership possibilities, a specific breakdown of tasks is difficult to make at this time. In addition, other activities, such as data fusion, will be accomplished externally to this activity's work scope but will have major implications for the dynamic route guidance system. Therefore, the following main tasks are an outline representation of the overall scope of work associated with this effort:

1) Review previous experience with dynamic route guidance (CDOT).

2) Determine fundamental requirements for dynamic route guidance in the metro area (CDOT).

3) Proposal process and selection of approved commercial route guidance system supplier (CDOT).

4) TOC software development (CTI).

5) System deployment (supplier).

6) Commercial operation and marketing of in-vehicle devices (supplier).

This activity is seen as providing the private sector a significant opportunity for designing, deploying and marketing a dynamic route guidance system. Private sector product development of this nature should appeal to many firms, both local and national, due to its expected market potential. In particular, two areas of interest seem appropriate for private sector involvement--in-vehicle navigational units, and communications.

In-vehicle navigation units provide the private sector with a marketable product for sale to consumers. Since this project is scheduled for deployment in the medium term, it is anticipated that ongoing developments in other areas will have produced attractive and affordable units by this time.

On the communications side, various methods exist for transmitting messages between the vehicles and the Denver area TOC. Typical RF communications networks, spread spectrum radio and RF beacon systems are but a few of the communications options available. By the time the route guidance system is implemented, FHWA will have developed a national systems architecture which will provide guidelines on these technical issues. The metro area system is expected to adhere to these standards, while exploring new approaches with FHWA support where necessary.

Project Schedule and Cost

At this time, dynamic mute guidance systems are still in the stages of development and evaluation. The Denver area could initiate its own dynamic route guidance system venture in the medium- to long-term, by which time the technology is expected to be proven and available for commercial deployment. The schedule associated with installation of a system in the Denver area will be dependent on technical advances in the next few years, together with the desires of the private sector with respect to route guidance commercialization.

It is anticipated that most of the costs associated with dynamic route guidance will be coveted by private sector suppliers. The potential return on both in-vehicle products and communications services suggests that public funding for these components will be unnecessary. However, since the Denver area TOC will provide the information processing base for real-time dynamic travel conditions, the TOC will need to collect, format and distribute the appropriate data for the dynamic route guidance system selected. This is likely to require software modifications to provide a compatible format for private sector initiatives. The cost of these software modifications, together with other state activities associated with this initiative, is estimated at $500,000

Project Funding

Private sector funding is expected for most aspects of any dynamic route guidance systems. Sales of in-vehicle navigation units and service subscriptions fees are expected to be commercially attractive to the private sector at the time of implementation locally. Because of this potential financial windfall, private sector support in the form of in-kind software or equipment deployment is a real possibility. This could offset state costs associated with software development or other activities at the TOC related to route guidance. If the bid process outlined previously is adopted, potential suppliers should be required to outline state responsibiities and associated costs as part of their system installation proposals.

ELECTRONIC SIGNAGE

Objective

The main objective of this activity is to increase both driver awareness of road signs and overall highway safety. Electronic signage involves the display of in-vehicle images replicating road signs. Liquid crystal, CRT, and head-up displays, in addition to infrared and microwave road-to-vehicle communication devices, comprise the primary components of an electronic signage system. This system would support both static and dynamic road signs (real-time VMS units), communicating the information to the in-vehicle display unit. The approach could be particularly beneficial during conditions of poor visibility, when drivers might otherwise be unable to see signs at the roadside.

Priority

Implementation of an electronic signage system has the potential to make a major contribution to road safety in the Denver area, particularly during winter driving conditions. The short-range transfer of digital messages from roadside controllers to in-vehicle display units will provide the motoring public real-time, location-specific traffic and travel information. It is anticipated that the Denver metro area could incorporate an electronic signage system into its overall ATIS program in the medium-term to long-term timeframe. Initial use will probably occur in government vehicles, with public involvement expected in the longer-term.

Applicable IVKS Goals

The electronic signage activity will primarily address the Denver area IVHS goals which follow:

- Increase transportation safety.
- Reduce congestion/improve mobility.
- Support real-time travel information.
- Minimize effects of incidents.
- Provide operational improvements through technology.

Activity Interrelationships

The Denver area TOC will support the operation of an electronic signage system for the metro area. The TOC will collect area-wide traffic information and process the real-time data in order to generate messages for VMS units, and other ATIS outlets. With electronic signage, this information can also be transmitted via road-to-vehicle communications for in-vehicle display. In addition, the TOC can calculate dynamic speed limits during congestion or bad weather, which again can be relayed into vehicles via electronic signage.

Beyond the TOC, this activity will be significantly enhanced by prior implementation of the following:

- Collection of real-time traffic volume and speed information.
- Expanded freeway ramp metering.
- TOC database integration and data fusion.
- Incident detection and management.
- Develop permanent communications network.

The automatic speed control activity will follow directly from this project, if electronic signage proves acceptable for use in the Denver metro area.

Approach

This activity will focus its initial efforts on the Denver area freeway system. It is therefore anticipated that CDOT will be the lead agency responsible for overseeing the deployment of an electronic signage system.

It is envisioned that the electronic signage system's roadside units will feature communication links to the Denver TOC in order to receive real-time traffic, travel and weather information as well as static and dynamic sign details. It is also possible that the system's roadside controllers could be coordinated with an AVI-based beacon network if that is the direction chosen for dynamic route guidance in the Denver area. In addition, in-vehicle display units will be required to present messages received from the roadside units.

Due to the innovative nature of this project, it is seen as an appropriate project for a federally-sponsored operational test. This would involve formation of a public-private partnership to undertake the project and evaluate the system. CDOT would lead the formation of this team and could solicit support from FHWA, NHTSA and several local telecommunications and electronics firms.

Scope of Work (SOW)

This activity will integrate component technologies required for operational testing of a prototype system. The following tasks outline the scope of work associated with this activity:

1) Identify public and private sector partners for participation in the operational test (CDOT).

2) The project team, through a series of working groups, will define the scope of the operational test, including the following tasks:

   - Review available technologies (e.g., in-vehicle displays, RF/AVI beacons, etc.) applicable to the system.

- Confirm needs to be addressed by the electronic signage system and determine optimal approach.
- Identify and assess locations for potential demonstration corridor(s).
- Determine functional and performance requirements for the system and undertake system design
- Identify hardware and software integration needs.
- Define scope of operational test implementation and nature of evaluation.

3) Develop operational test proposal and solicit federal funding support (project team).

4) Hardware and software development and integration (private) sector partners).

5) System implementation in selected demonstration corridor(s) and operational evaluation (project team).

It is anticipated that trial evaluation of in-vehicle signage could be performed using government vehicles supplied by CDOT, CSP or other local agencies. If the operational test proves the system a success, it may be expected to enter fell service in the metro area shortly after completion of the project. Initial use would probably be limited to government vehicles, but the system could subsequently be marketed to private citizens as a safety device.

Project Schedule and Cost

The project approach presented above has outlined a series of tasks that will advance this activity through to readiness for full system implementation. Corresponding schedule and cost estimates for this activity are as follows:

		Duration	cost
1)	Project team formation (SOW Task 1)	4 months	$50,000
2)	Needs assessment, system functional design and proposal preparation (SOW Tasks 2-3)	9 months	$15O,000
3)	System development and integration (SOW Task 4)	4 months	$200,000
4)	Implementation and operational evaluation (SOW Task 5)	6 months	$250,000
		TOTAL: 23 months	$650,000

It is anticipated that the operational test activity could begin in the medium term. If the operational test proves the system a success, subsequent follow-up implementation will depend in large part on the approach taken toward infrastructure deployment. Where

possible, these efforts should be coordinated with other compatible program activities such as AVI-based beacon systems for route guidance.

Project Funding

As discussed previously, this project is expected to be appropriate for consideration as a federally-supported operational test. At this time, FHWA is distinguishing in-vehicle safety advisory and warning systems (IVSAWS) as high IVHS priorities. In fact, IVHS America's funding recommendations for 1994 and 1995 include $10 million for in-vehicle signing operational tests. Therefore, it may be worth accelerating the schedule for this project to better match these allocations. The estimated medium term start date is consistent with the Strategic Plan and direction received from the IVHS program Task Force. Electronic signage is sufficiently advanced to allow earlier project implementation, if desired, however this activity would still need to be tested after implementation of the TOC.

This potential for partial federal funding can be obtained if at least a 20 percent local hard match accompanies the request. It is expected that this match will be drawn from contributions from CDOT and other local participating agencies, as well as the private sector partners which have an interest in developing a commercial product. The private sector would supply the hardware and software to be evaluated, while the government agencies would provide test vehicles. As project coordinator, CDOT would take the lead in securing the necessary fending commitments from involved partners, prior to submitting a proposal to FHWA.

AUTOMATIC SPEED CONTROL

Objective

This activity will build directly on an earlier element of the IVHS program. It will integrate the Denver area's electronic in-vehicle signage system with advanced speed control approaches. This will allow vehicle speeds to be automatically adjusted according to electronically-posted speed limits.

Implementation of this activity should strengthen overall surface transportation safety by optimizing traffic flow and speed, ensuring compliance with speed limits during hazardous driving situations, and preventing speed-related accidents. Automatic speed control is envisioned as a type of "corridor cruise control" that will maintain a cap on vehicle speeds when dictated by travel or road conditions. This activity is seen as a precursor for further advanced vehicle control systems (AVCS) and automated highway system (AHS) concepts.

Priority

Implementation of this activity is seen as an important early step in developing the Denver metro area's contribution to the federally-proposed AHS network. In its own right, the project could lead to significant accident reductions, with the follow-on benefit of reduced highway congestion. Due to the innovative nature of this project, which will involve removing partial vehicle control from the driver, its design, development and prototype system demonstration are seen as long-term timeframe activities.

Applicable IVHS Goals

This activity will primarily address the Denver IVHS goals which follow:

- Increase transportation safety.
- Reduce congestion/improve mobility.
- Provide operational improvements through technology.

Activity Interrelationships

The implementation of automatic speed control will, to a large extent, reflect integration of additional technologies with its direct predecessor, electronic in-vehicle signage. The extension of automatic speed control from this activity should be relatively straightforward if the electronic signage system design includes adequate consideration of the requirements for this follow-up effort. In addition, the Denver area TOC will retain its central role in processing travel information as well as providing monitoring and operational control capabilities for this project.

Additional activities that will provide significant input for automatic speed control include:

- Collection of real-time traffic volume and speed information.
- TOC database integration and data fusion.
- Dynamic route guidance.
- Develop permanent communications network.

Approach

The project approach recommended for this activity builds upon the project team established to implement electronic in-vehicle signage. It is expected that CDOT, FHWA, NHTSA and the private sector partners will continue their roles within this cooperative effort while expanding the project team to include automotive manufacturers and AVCS experts. It is anticipated that CDOT will maintain its lead role, with significant supporting contributions from the private sector partners.

In addition, this activity will provide an avenue for academic research. For example, the Colorado Transportation Institute (CTI) could provide significant input in human factors evaluation and simulation modeling for automatic speed control.

As with electronic signage, this project is seen as potentially appropriate for a federally-sponsored operational test. It could, in fact, represent a follow-up phase to the earlier electronic signage effort. The expanded project team outlined above will undertake the project and evaluate the system.

Scope of Work (SOW)

The following main tasks are representative of the scope of work associated with this effort:

1) Identify public and private sector partners for participation in the operational test (CDOT).

2) The project team, through a series of working groups, will define the scope of the operational test, including the following tasks:

   - Review the electronic Signage system's design, available technologies and previous experience with automatic speed control systems.
   - Confirm needs to be addressed by system.
   - Determine functional and performance requirements for the system.
   - Identify hardware and software development needs.
   - Define scope of operational test implementation and nature of the evaluation

3) Develop operational test proposal and solicit federal funding support (project team).

4) Hardware and software development (private sector partners).

5) System implementation and operational evaluation (project team).

It is anticipated that this activity's operational test will be performed on a small fleet of government vehicles. These will previously have been instrumented with electronic signage equipment, which will be connected with the brake and throttle actuators to allow automatic speed control. If the operational test proves the system a success, it may be expanded to wider use on local government vehicle fleets in the metro area.

In the future, public use of automatic speed control in the Denver area will necessitate a change in public perception of the transportation system's role in peoples' lives. It is anticipated that the institutional issues associated with this activity will play the predominant role in determining an appropriate implementation time schedule. The federal AVCS and AHS development effort will also help to identify the appropriate time for public deployment of automatic speed control, both in the Denver area and nationally.

Project Schedule and Cost

Implementation of the Denver area's automatic speed control system will build upon the foundation established within the electronic in-vehicle signage project. The project approach presented above has outlined a series of representative tasks to extend the electronic signage system to fully-operational automatic speed control. Corresponding schedule and cost estimates are as follows:

		Duration	cost
1)	Team formation (SOW Task 1)	3 months	$30,000
2)	System design and proposal preparation (SOW Tasks 2-3)	6 months	$100,000
3)	System development and operational evaluation (SOW Tasks 4-5)	8 months	$500,000
		TOTAL: 17 months	$630,000

It is anticipated that this activity will begin in the long term. The actual schedule will reflect the completion and results of the electronic signage effort, as well as federal developments and guidelines in the AVCS arena.

Project Funding

It is anticipated that this activity will be appropriate to qualify for federal funding support. This could be in the form of operational test funding or federal monies set aside for AVCS research, development and deployment.

CDOT is expected to assume responsibility for seeking funding support for this activity. This may include soliciting fending support from local government agencies and private industries.

Objective #7
Improve and Integrate Traffic Control Systems Region-Wide

Activities

Expanded Freeway Ramp Metering

Advanced Isolated Intersection Control and Simulated Signal Coordination

Reversible Lanes in Key Corridors

Adaptive Traffic Control

Air-Quality-Responsive Traffic Control

Fourth Generation Signal Control

EXPANDED FREEWAY RAMP METERING

Objective

Currently, CDOT monitors and operates a network of freeway ramp meters at 28 locations, in the east and south portions of the metro area along I-25 and I-225. These ramp meters control entry to Denver's freeway systems, and provide real-time traffic information in a tabular format to both CDOT and the private sector. See Figure A2 for existing ramp meter locations.

This activity reflects CDOT's plan to expand its freeway ramp metering system at a number of locations throughout the Denver area. In addition, CDOT is upgrading the ramp metering computer system to obtain greater control and monitoring flexibility, and to provide improved software for graphical displays of freeway speeds. This upgrade will include the current ramp metering network as well as the new ramp metering locations.

Priority

This activity is one of the most important early elements of IVHS implementation in the Denver metro area. The existing 28 ramps currently provide the only real-time traffic count and speed information on the regional freeway system. Ramp metering has been shown to reduce recurrent stop-and-go congestion on the mainline freeway, improve air quality, reduce fuel consumption, improve average travel speeds on the mainline freeway, and improve safety by reducing accidents (Reference 3). Expansion of the ramp metering system will therefore provide these benefits over a greater area, as well as supplying real-time data on which several ATMS and ATIS efforts will be based. Due to the overall importance of this activity, it has been included for implementation within the scope of the Early Action Plan.

Applicable IVHS Goals

This activity will primarily address the Denver area IVHS goals which follow:

- Reduce congestion/improve mobility.
- Increase transportation safety.
- Integrate existing operations and IVHS activities.
- Provide real-time travel information.
- Contribute to regional air quality goals.

Activity Interrelationships

The establishment of the Denver area TOC is central to this activity, since it will provide a focal point for CDOT's expanded ramp metering system along regional freeways. The main ramp metering computer, currently located in the CDOT Region Six building, will

be transferred to the TOC when the facility is completed. The TOC will then serve as the primary collection center for real-time traffic count and speed information from the ramp meter locations. In addition, the TOC will provide the necessary equipment to analyze and act on these data, and to view the upgraded ramp metering system computer's graphical displays.

As the ramp metering expansion continues, other IVHS activities will provide valuable input to this effort. These include:

- Collection of real-time traffic volume and speed information.
- Development of permanent communications network.
- TOC expert systems.

Many IVHS activities will be significantly enhanced by increased availability of data from the expanded ramp metering system. These include:

- TOC database integration.
- Data fusion.
- Incident detection and management.
- Development of cooperative exchange system with television and radio traffic information services.
- Dissemination of travel information region-wide (e.g., HAR, VMS, RDS, videotex).

Approach

CDOT is responsible for the existing ramp metering system in the Denver area and will lead this expansion effort. Currently, CDOT is in the process of developing performance specifications for the ramp metering computer system upgrade. Once this is completed, CDOT will request proposals and select a consultant to perform this work.

With the computer upgrade component already underway, the approach identified here concentrates on the physical expansion of the ramp metering system. It is anticipated that the majority of this work will be performed m-house by CDOT personnel. However, some initial design tasks could be undertaken by private firms under contract to CDOT. Close coordination of the ramp metering system's physical expansion and computer system upgrade will be necessary to ensure the overall success of this activity.

In addition, future ramp metering at both existing and proposed locations should be fully coordinated with the local agency having jurisdiction over the arterial street serving the interchange. Integration of ramp metering with signal progression along the arterial can provide benefits to both the arterial and freeway systems by reducing queues which interfere with operations along the arterial. These efforts will provide an excellent

opportunity for local agencies and CDOT to coordinate their work and cooperate in the implementation of IVHS activities.

Scope of Work (SOW)

Tasks within this activity concentrate on the physical expansion of the ramp metering system. The following main tasks will be included in the scope of work:

1) Prepare an inventory of current ramp metering equipment and locations in the Denver metro area (CDOT).

2) Establish requirements for expanded ramp metering (CDOT).

3) Develop procurement documents, request proposals, and select consultant (CDOT).

4) Once selected, the consultant, with CDOT, will address the following tasks:

- Evaluate the Denver area's additional freeway ramp metering needs.
- Identify and assess interchange locations for the expanded freeway ramp metering system.
- Review needs for bus/HOV bypass requirements within the system.
- Implementing ramp metering may, in some instances, require reconstruction of the ramp itself. If so, the consultant will provide the design for the improvements.
- Review available technologies (e.g., inductive loops, microwave, video image processing, Type 170 and NEMA controllers, etc.) and previous work, including liaison with bodies experienced in such systems.
- Determine functional requirements for the ramp metering system (hardware and software) and identify the most appropriate ramp metering equipment.
- Determine the appropriate level of data processing between field location (decentralized) and the Denver area TOC (centralized).
- Assess communications needs between field equipment and the ramp metering computer.
- Prepare design documents and specifications for the expanded ramp metering system within the Denver area.

5) Review and refine system design (CDOT/consultant).

6) Develop bid documents, bid contract, and procure ramp metering equipment (CDOT).

7) Expanded ramp metering system deployment including traffic sensors, controllers and communications links (CDOT).

Currently, CDOT utilizes inductive loop vehicle detectors and Type 170 controllers in its freeway ramp metering system. It is anticipated that, initially, CDOT will continue to make use of this equipment. However, as the expansion continues, CDOT should consider the use of technologies such as above-ground sensor systems. CDOT should also reevaluate its ramp metering algorithms to ensure their compatibility and efficiency with the new computer system and the expanded ramp network.

In addition, there are some projects currently underway in the Denver metro area which should be closely coordinated with this activity. These include the collection of real-time traffic volume and speed information, North I-25 TMS, and CDOT's freeway inductive loop installation program. These projects possess several elements in common with the expanded freeway ramp metering system. They should therefore be viewed in a broader, region-wide perspective to ensure overall program compatibility.

Project Schedule and Cost

This project can be grouped into three main areas with corresponding schedule and cost estimates, as follows:

		Duration	Cost
1)	CDOT preparatory work (SOW Tasks l-3)	3 months	$25,000
2)	Needs analysis, functional requirements and system design (SOW Tasks 4-5)	6 months	$250,000
3)	Equipment procurement and deployment (SOW Tasks 6-7)	15 months	$1,225,000
	TOTAL:	24 months	$1,500,000

This project can begin as early as 1994.

Project Funding

CDOT will be responsible for seeking funding support for this project. State sources are expected to provide the majority of the funding required for this activity.

ADVANCED ISOLATED INTERSECTION CONTROL AND SIMULATED SIGNAL COORDINATION

Objective

This activity will involve deployment and evaluation of advanced isolated intersection control strategies in the Denver area. Such approaches utilize vehicle detectors installed significantly in advance of intersections to control traffic signals. Early detection allows the signal controller to automatically compare the option of stopping approaching vehicles on one route with holding already-stopped vehicles for a few more seconds on the other route. The intersection can then be controlled for maximum throughput and minimum emissions.

Conceptually, using several isolated intersection controllers, adaptive signal coordination may be simulated along an arterial section without requiring communication links or a main computer. The concept is that since each isolated controller would optimize signal settings for the corresponding intersection, the overall arterial would also be optimized. A prime objective of this activity is to evaluate a trial deployment of this technique at an appropriate metro area location.

Priority

Advanced isolated intersection control has the potential to improve traffic and air quality conditions in outlying areas of the metro area. This will complement enhancements in the central region. An early trial of advanced isolated intersection control would serve to establish whether there is potential for widespread system operation. Similarly, evaluation of the simulated signal coordination concept will determine the operational feasibility of this approach. This will include evaluation of the ability to achieve the benefits of coordinated adaptive control, without requiring local authorities to relinquish control of their signal systems. The project is included in the Early Action Plan as a potential test activity, so that trial results can provide the basis for decision making in appropriate signalized areas.

Applicable IVHS Goals

This activity will primarily address the Denver area IVHS goals which follow:

- Reduce congestion/improve mobility.
- Provide opportunities for private sector participation.
- Provide operational improvements through technology.
- Contribute to regional air quality goals.

Activity Interrelationships

The TOC will not provide significant input to this activity, since the signal systems under consideration will, by definition, operate in isolation. However, data collected by the systems could be relayed back to the TOC, to provide an indication of traffic flows in outlying areas.

Because of this isolation, this activity can potentially be undertaken as an independent project in the first instance. If initial trials lead to full-time deployment, however, the system may subsequently be enhanced by the following ongoing IVHS initiatives:

- Advanced arterial surveillance.
- Air quality-responsive traffic control.

Approach

This activity will be undertaken as an operational test of new and emerging approaches, rather than as a deployment venture. The results of the test will be used to draw conclusions on full-time system application. Since this activity focuses on signalized intersection control strategies, the jurisdiction/agency which maintains the intersection should be the party responsible for overseeing the effort.

DRCOG could also play a role in this effort, building on its current regional traffic signal timing program. DRCOG could additionally help to transfer the results of the study to application at other signalized intersections after the initial operational test is completed.

If the operational test approach is pursued, these players would form a team and develop a detailed description of the project to be undertaken. The team could include signal hardware and software controller manufacturers, providing equipment and expertise needed in the project. The team's ideas would be submitted to FHWA as a proposal. If selected, this would effectively lead to FHWA becoming a partner in me project.

Scope of Work (SOW)

Trial implementation of the strategies under investigation in this project could be undertaken in many outlying locations within the region. Additional follow-up implementation will reflect the results of an initial trial. The following tasks are representative of the scope of work associated with the operational test activity:

1) Establish team (agency/jurisdiction/signal company).

2) Define scope, budget and team members' responsibilities for the operational test (team).

3) Prepare and submit proposal for operational test funding (team). Note: activities from here are dependent on receipt of funding.

4) Implement trial system at a single, isolated intersection (agency/signal company).

5) Evaluate trial system and assess scope for simulated signal coordination (team).

6) Implement system at several adjacent intersections for simulated signal coordination (agency/signal company).

7) Evaluate simulated signal coordination (team).

8) Assess scope for use of isolated intersection control or simulated signal coordination elsewhere in the metro area (DRCOG).

Project Schedule and Cost

The project approach presented above has outlined a series of representative tasks that will advance isolated intersection control concepts through to an operational demonstration. This will provide the basis for permanent deployment at outlying metro area locations, if appropriate. The number of intersections to be instrumented, and corresponding costs, will depend on the results of the initial trials. Therefore, cost and schedule estimates are limited to the operational test activities, as outlined below:

	Duration	Cost
1) Establish team, define project and seek funding (SOW Tasks l-3)	8 months	30,000
2) Initial system implementation (SOW Task 4)	2 months	50,000
3) Initial system evaluation (SOW Task 5)	2 months	60,000
4) Installation at multiple intersections (SOW Task 6)	2 months	120,000
5) Simulated signal coordination evaluation	6 months	150,000
	Total 20 months	410,000

It is anticipated that this activity's efforts could get underway immediately.

Project Funding

As discussed previously, this project should be undertaken as an operational test if Possible. This suggests that federal funding support may be available. Potential avenues for such support include FHWA's operational test program, corridors program, or IVHS-IDEA program

If a request for federal funding is successful, some matching funding will likely be required. The project partners would need to contribute to ensure the necessary matching funding level is reached. This could be achieved through the involvement of a traffic signal systems company as part of the team.

REVERSIBLE LANES IN KEY CORRIDORS

Objective

This activity will focus in two areas. The initial priority would include a study to define conditions in which reversible lanes might be considered appropriate by the operating agencies. Considerations might include highly directional flows by the time of day, corridor development and access control, available right-of-way, and so on.

The second priority would focus on the development of reversible lanes along appropriate arterials as an operational test project. For the arterial systems, most of the initial activities in the Denver area IVHS Program focus on improving signal systems and coordination. However, the establishment of reversible lanes in key corridors is a further technique to improve the efficiency of the arterial system. The prime objective of this activity would be to determine how monitoring and control of a reversible lane could be improved through the application of IVHS technologies. The City and County of Denver has indicated a willingness to participate in this activity.

Priority

Regardless of freeway system improvements, it is unrealistic to expect the network as a whole to operate effectively without also directing attention to the arterial street system. Increasing the capacity of the arterial network is an important goal of IVHS implementation in the Denver area and the initial effort in particular would enhance the applicability of reversible lanes as a tool for addressing specific mobility deficiencies. The establishment of reversible lanes in key corridor locations offers the potential to improve the efficiency of the regional arterial system. This activity has been included for implementation within the scope of the Early Action Plan.

Applicable IVHS Goals

This activity will primarily address the Denver area IVHS goals which follow:

- Reduce congestion/improve mobility.
- Efficient use of tax dollars.
- Ensure high benefit/cost ratio.
- Minimize new construction/maintenance costs.
- Contribute to regional air quality goals.

Activity Interrelationships

The TOC has the potential to play an important role in the implementation of this activity. Monitoring and control aspects of the reversible lanes could be improved through the application of IVHS technologies centered within the TOC, in conjunction with distributed

field controllers. The equipment could monitor the arterial for the optimum time to initiate reversible lane use and then deploy signing techniques and traveler information advisories to control motorist usage. Traffic signal timing plans could also be adjusted automatically to reflect reverse operation.

In addition, several activities can contribute to or be approached in conjunction with the study and implementation of reversible lanes. These include:

- Advanced arterial surveillance.
- TOC database integration.
- Data fusion.
- Preplanned incident diversion routes.
- Develop permanent communications network.
- Integrated demand management.

Approach

This activity seeks to study the efficiency of reversible lanes as a strategy to improve operation of the Denver area's arterial system, and then establishing reversible lanes in key test corridor locations. It is anticipated that the majority of work associated with the initial study and with the development of IVHS approaches for reversible lane control would be accomplished through consultant support. With regard to deployment, the government agency (e.g., CDOT, city or county traffic department) responsible for maintaining a specific route would manage the effort along that particular highway.

DRCOG could serve as the lead agency responsible for coordinating this activity, however all work tasks would involve a project team that would likely include CDOT and local governments. DRCOG would also oversee the affiliated agencies' efforts and assist in the route selection process. In addition, DRCOG's assistance would ensure standardization among all reversible lane practices and promote cooperation among jurisdictional agencies.

Scope of Work (SOW)

Implementation of reversible lanes will likely be undertaken in a phased approach. The first stage of the activity would be a study in which the parameters of using reversible lanes as a tool to address congestion would be seet. These guidelines could then be applied accross the Denver area to identify and prioritize the appropriate corridors. The second stage of the activity could involve a development contract for system design, deployment and evaluation in a selected trial corridor. The following main tasks are representative of the scope of work associated with this effort:

1) Select study consultant (DRCOG/CDOT).

2) Develop reversible lane guidelines (DRCOG/CDOT/various agencies/consultant).

3) Identify, prioritize and select reversible lane locations (DRCOG/CDOT/agencies/ consultant).

4) Define project scope, develop RFP and request proposals, and select design consultant (DRCOG/ affiliated agency).

5) Once selected, the design consultant will address the following tasks:

- Evaluate the reversible lane corridor's monitoring and control needs, consistent with efficient operational policies.
- Review available technologies (e.g., inductive loops, overhead lane control signing, video image processing, etc.) and existing infrastructure.
- Determine functional requirements for reversible lane control.
- Prepare design documents and associated materials for the trial deployment of an IVHS-controlled reversible lane corridor.

6) Review and refine system design (DRCOG/affiliated agency).

7) Develop bid documents, bid contract and select trial system supplier (DRCOG/ affiiated agency, with consultant support).

8) Deploy reversible lane corridor's software and hardware for operational evaluation (supplier).

9) Implement TOC interconnections (CDOT/supplier).

10) Operational evaluation and system refinement (DRCOG/affiliated agency/consultant).

After this first trial implementation, the results will be used to make decisions on IVHS-based reversible lane control at other metro area locations. If the approach proves successful, new reversible lane operations may be introduced, while previously operating facilities may be upgraded through addition of the IVHS monitoring and control elements.

Project Schedule and Cost

The project approach presented above has outlined a series of representative tasks that will advance reversible lane concepts through to development and trial implementation. Corresponding schedule and cost estimates are as follows:

	Duration	cost
1) Study Phase (SOW Tasks l-3)	6 months	$25,000
2) Preparatory work (SOW Task 4)	2 months	$25,000
3) System design (SOW Task 5)	8 months	$150,000
4) Design review and supplier selection (SOW Tasks 6-7)	4 months	$50,000
5) Deployment and evaluation (SOW Tasks 8-10)	6 months	$175,000
TOTAL:	26 months	$425,000

This work could begin immediately. It is anticipated that a number of corridors in the Denver area could benefit from this activity. Costs of deploying equipment along these corridors will depend on the nature of the system design.

In parallel with the development of the IVHS control and monitoring systems, there is no reason to delay reversible lane deployment in appropriate corridors. Reversible operations in such corridors could be upgraded from time of day to automated operation based on the results of the initial project.

Project Funding

DRCOG, as the likely team leader of this activity, would also be responsible for seeking fundiig support. Funding sources for the project include federal, state and local funds. Due to the innovative nature of the project, it may be possible to gain funding support through initiatives such as FHWA's IVHS IDEA program.

ADAPTIVE TRAFFIC CONTROL

Objective

This activity's efforts will result in a test project to demonstrate real-time adaptive traffic control in the Denver area. These systems monitor traffic conditions and will react in real-time to changing traffic patterns by implementing the appropriate signal settings and are perhaps most appropriate for real-time control during special or unexpected traffic events. Principal examples of real-time adaptive traffic control systems include SCOOT (Split, Cycle and Offset Optimization Technique) in the United Kingdom and Canada; SCATS (Sydney Coordinated Adaptive Traffic System) in Australia; and Oakland County, Michigan.

This activity will evaluate the merits of such systems and determine the appropriate conditions in which they may apply, then select an adaptive traffic control system and undertake any modifications required to facilitate desired operation in the Denver area. The approach potentially could be demonstrated along a pie-planned diversion route, in the vicinity of a sports stadium, regional shopping centers, along the MAC line in downtown Denver, or any other highly-visible demonstration areas.

Priority

Implementation of this activity is seen as highly important to the ATMS elements of IVHS in the Denver area. Adaptive traffic control should be particularly beneficial in the area due to its ability to constantly readjust traflic signals under unusual traffic conditions. The approach is also immune to aging of signal timing plans, which can quickly render a fixed-time plan inappropriate. In addition, real-time adaptive traffic control systems have the potential to improve and integrate traffic control systems region-wide. Site evaluations for this activity's demonstration project could be initiated in the short-term with implementation occurring in the medium-term timeframe.

Applicable IVHS Goals

This activity will primarily address the Denver area IVHS goals which follow:

- Reduce congestion/improve mobility.
- Successfully cross interjurisdictional boundaries.
- Minimize the effects of incidents.
- Ensure high benefit/cost ratios.
- Provide operational improvements through technology.

Activity Interrelationships

Real-time adaptive traffic control systems are seen as an "on-street" distributed intelligence system for the metro area. This activity will coordinate with, but not be controlled by, the

Denver area TOC. Rather, the TOC will monitor the status of the adaptive traffic control system and communicate information to the system as required. The TOC will also benefit from the collection of traffic data used to adjust traffic signals in real-time.

Other activities that are significantly interrelated with the implementation of the adaptive traffic control system include the following:

- Collection of real-time traffic volume and speed information.
- Advanced arterial surveillance.
- Preplanned incident diversion routes.
- Fourth-generation signal control.

Approach

This activity will determine if adaptive traffic control techniques are appropriate for implementation in the Denver area, and if so, will deploy a real-time adaptive traffic control system on a selected portion of the metro area's street network. DRCOG currently coordinates a regional traffic signal system improvement program to improve traffic signal operations across jurisdictional boundaries and would appear to be the logical candidate to oversee this activity's efforts.

In addition to DRCOG, other appropriate project participants would be the participating local agencies which have jurisdiction over the roadways on which the adaptive traffic control system is implemented. The TOC Systems Engineer would be responsible for implementing any equipment or software necessary to monitor adaptive control operations at that facility.

Although adaptive traffic control systems have been applied quite widely elsewhere in the world, the first North American installations have just been undertaken--SCOOT in Toronto, Ontario and SCATS in Oakland County, Michigan. Since this activity is scheduled for the medium-term timeframe, it is expected that the Denver area will deploy only proven, available technologies. Currently, FHWA is sponsoring a study entitled "Evaluation of Developments Under Real-Time Adaptive Traffic Control for IVHS." This project's results, along with liaison with other transportation agencies, will provide valuable input to the Denver area in its evaluation and selection of the appropriate adaptive traffic control system. It is anticipated that the work will follow a traditional approach, in which the system design will be prepared by a consultant, and implementation will be undertaken by a contractor.

Scope of Work (SOW)

The following main tasks are expected to be included within this activity's scope of work:

1) Review current adaptive traffic control systems, their merits and appropriate application, and potential trial locations in the Denver metro area (DRCOG/CDOT).

2) Prioritize and select trial locations (DRCOG/CDOT).

3) Develop procurement documents, request proposals, and select design consultant (DRCOG/CDOT/affiliated agency).

4) Once selected, the design consultant, with DRCOG, CDOT, and the affiliated agency, will address the following tasks:

- Evaluate each trial location's adaptive traffic control system needs.
- Review available adaptive traffic control systems (e.g., SCATS, SCOOT, etc.) and previous work, including liaison with bodies experienced in such systems.
- Determine functional and performance requirements for the adaptive traffic control system.
- Assess the applicability of current signal control systems and equipment.
- Assess communication needs within the system's components and with the Denver area TOC.
- Prepare design documents and plans for adaptive traffic control system demonstration project.

5) Review and refine system design (DRCOG/CDOT/affiliated agency/consultant).

6) Develop bid documents, request proposals, and select equipment supplier (DRCOG/ CDOT/affiliated agency/consultant).

7) Deploy adaptive traffic control demonstration project for operational evaluation (supplier/affiliated agency).

8) Evaluate trial deployment and refine system operational procedures, as required (DRCOG/CDOT/affiliated agency/consultant).

The scope of work presented above provides an outline for a metro area adaptive traffic control demonstration project. It is anticipated that a suitable demonstration project could encompass approximately 60 signalized intersections within three distinctly different operational control areas. This would allow the project to evaluate adaptive traffic control under various types of operating and road environment conditions. Three potential areas are identified below:

- The first control area could include about 20 intersections along the MAC line within the grid network of Denver's CBD or an adjacent location within the urban core area. The downtown or core area would provide a mixture of traffic patterns throughout the day and would allow constant evaluation of the system.

- The second control area could include about 20 intersections around a major sports stadium or shopping center. This testbed area would provide unusual and highly variable traffic conditions for the selected system to accommodate.

- The third control area could include about 20 intersections along a major uncontrolled access arterial.

Project Schedule and Cost

The project approach presented above has outlined a series of tasks that will advance this activity through to a demonstration in three locations. Corresponding schedule and cost estimates are as follows:

	Duration	cost
1) DRCOG preparatory work (SOW Tasks 1-3)	4 months	$40,000
2) System design (SOW Task 4)	6 months	$200,000
3) Design review and supplier selection (SOW Tasks 5-6)	4 months	$40,000
4) System implementation at trial locations (SOW Task 7)	12 months	$2,600,000
5) System evaluation and refinement (SOW Task 8)	4 months	$50,000
TOTAL:	30 months	$2,930,000

The cost estimate assumes that every intersection in the demonstration areas is under adaptive traffic control. In addition, the cost estimates include all installation costs (e.g., controllers, loop detectors, communication lines, etc.) as well as operating and maintenance costs associated with this activity for one year. It is anticipated that this activity's efforts could get underway in the medium term.

Project Funding

DRCOG will be responsible for seeking funding support for this demonstration project. The majority of funds are expected to be drawn from federal sources such as IVHS monies set aside under ISTEA. In addition, state and local funds could contribute to this project to offset both equipment procurement costs and installation costs along the selected trial corridors.

AIR-QUALITY ADAPTIVE TRAFFIC CONTROL

Objective

This activity would investigate opportunities for the preservation of air quality in the Denver area through advanced traffic signal control strategies, specifically responding to periods of high air pollution with an adaptive system similar to that discussed in the prevous section. In this case the control system would "adapt" to air quality parameters instead of traffic conditions. It would aim to develop a responsive signal control system based on measured traffic flows and air quality data recorded at pollution "hot spots." This is seen primarily as a research and development activity due to the unproven nature of this type of control system at this time. The activity could help to improve the accuracy of current air quality computer models and combine these with air pollution meters to develop a prototype system.

Within the European DRIVE program, ongoing developments are seeking to reduce environmental pollution in major CBDs through IVHS-based traffic operation and control measures. In Athens, for example, an integrated approach combining pollution monitoring systems, pollution prediction computer models, urban traffic signal control, AVI beacons, CCTV cameras, VMS units, and dynamic route guidance is being considered for a comprehensive IVHS-based air-quality-responsive traffic control system.

Similar oppommities could be examined for the Denver area in this project. Implementation of such a system in the region would confirm Denver's commitment to environmental protection and air quality, as well as improving the natural view of its scenic mountain skyline and the quality of life for local residents.

Priority

The Denver area frequently experiences poor air quality and visibility due to the presence of air pollutants and particulates. Since air quality is of major concern to Denver residents, the evaluation of IVHS-based technologies to reduce environmental pollution is an important priority within the metro area's IVHS Master Plan. The research and development of an air-quality adaptive traffic control system in the region will integrate several previously implemented metro area IVHS elements. This activity is seen as appropriate for the medium-term and long-term timeframes for research and deployment, respectively.

Applicable IVHS Goals

The major goal of this activity is to contribute to regional air quality goals in the Denver metro area. This activity will also address the Denver area IVHS goals which follow:

- Provide operational improvements through technology.
- Integrate existing operations and IVHS programs.
- Successfully cross inter-jurisdictional borders.

- Provide opportunities for academic research.
- Establish Colorado as an IVHS technology leader.

Activity Interrelationships

The Denver area TOC will play a central role in the development of the metro area's air-quality adaptive traffic control system. The TOC will collect traffic flow information, could collect air-quality information, and could also house and operate the pollution prediction computer models which will provide input to the appropriate traffic control strategies.

In addition, several other activities will provide significant input to the implementation of an air-quality-responsive traffic control system. These include:

- Collection of real-time traffic volume and speed information.
- Advanced arterial surveillance.
- TOC database integration and data fusion.
- Develop permanent communications network.
- Adaptive traffic control.

Approach

Air-quality adaptive traffic control is expected to operate most effectively as a region-wide program. Therefore, DRCOG is well positioned to serve as the overall coordinating entity for a research and development test project of this type due to their established role as a jurisdictional facilitator.

Because of the region-wide perspective of this project, appropriate participants include various local agencies having jurisdiction over roadways in the selected deployment area. CDOT's involvement will allow the initiative to integrate previously-implemented IVHS program elements within the air-quality adaptive traffic control system. This innovative IVHS-based approach to address areawide air pollution problems should also attract support from both FHWA and EPA.

As mentioned, air-quality adaptive traffic control systems are one of the less advanced approaches within the IVHS environment, and possess the potential for numerous, inter-related research activities. This research component could be undertaken by members of CTI, for example in developing advanced air quality computer modeling suites and data integration/fusion software.

Due to the innovative nature of this project, it is seen as potentially appropriate for a federally-sponsored research, development and operational test effort. A team comprising the public agencies outlined above and traffic signal system suppliers could be formed to undertake the project.

Scope of Work (SOW)

It is anticipated that actual implementation of an air-quality adaptive traffic control system in the Denver area will occur through integration of several previously implemented IVHS activities and development of advanced air quality computer models. The following main tasks are representative of the scope of work associated with this effort:

1) Identify air pollution hot spots (DRCOG).

2) Identify public sector, private sector and academic partners for participation in the project (DRCOG).

3) The project team, through a series of working groups, will define the scope of the project, including the following tasks:

   - Review available technologies (e.g., air quality computer models, pollution meters, etc.) applicable to the system.
   - Confirm needs to be addressed by system.
   - Determine functional and performance requirements for the system.
   - Identify and evaluate integrated system concepts.
   - Assess communication needs between system components and the Denver TOC.
   - Identify hardware and software development needs.
   - Prepare prototype design and operational procedures for an air-quality-responsive traffic control system.
   - Identify potential demonstration areas.
   - Define scope of operational test implementation and nature of evaluation.

4) Develop research and development proposal and solicit federal funding support (project team).

5) Hardware and software development and integration (project team).

6) System implementation, evaluation and refinement (project team).

If the research and development effort during the medium term proves the system has positive potential, it could enter full service as an operational test in the metro area in the long-term IVHS timeframe. Responsibility for this implementation would lie in part with the local government agencies, who would support integration of the approach with local traffic signals. CDOT would be responsible for integrating various other IVHS activities and

interfacing with the Denver area TOC. DRCOG could support the overall coordination of the full-scale deployment effort.

Project Schedule and Cost

This activity will aim to integrate several previously implemented IVHS elements with new monitoring and control capabilities. The use of existing IVHS components should minimize the investment required in system infrastructure, while still allowing the project objectives to be met. Corresponding schedule and cost estimates for the activity are as follows:

	Duration	Cost
1) Project team formation (SOW Tasks l-2)	4 months	$50,000
2) Needs assessment, functional requirements and system design (SOW Task 3)	15 months	$600,000
3) Design review and proposal preparation (SOW Task 4)	4 months	$50,000
4) System development and integration (SOW Task 5)	9 months	$800,000
5) Implementation and refinement (SOW Task 6)	12 months	$1,600,000
TOTAL:	44 months	$3,100,000

It is anticipated the research portion of that this activity will start in the medium-term. Any deployment or testing would occur in the long-term.

Project Funding

This activity will aim to achieve major breakthroughs in the preservation of air quality through use of IVHS technologies. Due to its innovative nature, the project may be considered for federal funding through EPA or FHWA. Such a funding request would be made through submission of a research and development proposal, as outlined in the scope of work. For the earlier stages of the project, DRCOG would take the lead in securing the necessary contributions form the various participants. DRCOG could also seek a federal grant to cover the performance of this initial work.

FOURTH GENERATION SIGNAL CONTROL

Objective

This activity will aim to design a signal control system that overcomes the limitations of existing traffic signal management technologies. Fourth generation signal control systems will provide functions such as fast-response remedial plans, short-term forecasting, increased feedback on network traffic conditions and explicit, policy-related intervention strategies for use by highway agencies. The components of such a system will build on technology developments from other IVHS initiatives as well as earlier elements of the metro area Master Plan.

Integration of emerging IVHS technologies such as infrared sensors, adaptive traffic control systems, video image processing, probe-based data collection systems and driver information systems will allow future traffic signal timings to automatically reflect a variety of factors. In addition to current traffic conditions, these will include incident response plans, air pollution levels and vehicle route selection. The project will therefore harmonize traffic signal control with many other IVHS technologies, such that the highway system as a whole functions interactively. In addition, this activity should improve incident response time by coordinating the traffic signal control network with the Denver area's emergency response vehicle fleet.

Priority

Fourth generation signal control will involve the integration of several previously deployed **metro** area IVHS activities. It has the potential to achieve significant benefits in overall network coordination, reducing congestion, delay and vehicle emissions. However, the project is seen as an overlapping step, building on earlier program activities, rather than as a project which can be pursued independently. It represents an advanced IVHS effort, with a great deal of research, and is included in the long-term timeframe of the Denver area IVHS Master Plan.

Applicable IVHS Goals

This activity will primarily address the Denver area IVHS goals which follow:

- Integrate existing operations with IVHS activities.
- Reduce congestion/improve mobility.
- Encourage private sector participation.
- Provide opportunities for academic research.
- Provide operational improvements through technology.
- Establish Colorado as a technology leader.

Activity Interrelationships

Many other IVHS activities have the potential to contribute to fourth generation signal control. The Denver area TOC will play a central role within this activity, through its control of the various IVHS technologies which will provide input to the system. The TOC will coordinate the various traffic and weather information collection systems and database integration and fusion processes that will facilitate interactive signal operation.

In addition, the following activities will likely play an integral role in the development of fourth generation signal control strategies:

- Collection of real-time traffic volume and speed information.
- Incident detection and management.
- Development of permanent communications network.
- Advanced arterial surveillance.
- Adaptive traffic control.
- Air-quality-responsive traffic control.
- Dynamic route guidance systems.

Approach

Fourth generation signal control is perhaps the most conceptual of all the IVHS activities discussed in the Master Plan. For this reason, it is unrealistic to believe that an accurate approach and scope of work can be developed at this stage. Rather, the project will reflect the results and capabilities of earlier IVHS efforts, as well as technology advancements in the next few years. However, a general outline of the project approach is presented below.

Fourth generation signal control will integrate multiple, independent IVHS activities into a single, comprehensive traffic management approach. This will require an evaluation of all previously implemented IVHS activities throughout the Denver area to determine their potential role within the scope of this program. To facilitate this activity, joint leadership between CDOT and DRCOG may be appropriate.

Their involvement will likely be complemented by the participation and support of several other local agencies. The exact composition of the project team can be determined once the scope of the project is defined in more detail.

There are also opportunities for academic or private sector input to this project. These are associated with the complexities of the activity, and the potential to research into alternative ways of combining data and integrating activities.

Scope of Work (SOW)

Specific tasks to be undertaken in this project will reflect the technologies to be integrated and control approaches to be pursued. The following main tasks are representative of the scope of work associated with this activity:

1) Identify potential technologies for inclusion within the Denver area's fourth generation signal control system (CDOT/DRCOG).

2) Identify public sector, private sector and academic partners for participation in the initiative (CDOT/DRCOG).

3) The project team, through a series of working groups, will define the scope of the effort, including the following tasks:

   - Review list of potential IVHS activities and prioritize for program inclusion.
   - Review available technologies and previous work with interactive signal control systems.
   - Determine functional and performance requirements for the system.
   - Identify hardware and software development needs.
   - Assess communication needs between components and with the Denver TOC.
   - Prepare integrated system design and operational procedures.
   - Identify potential test area.

4) Develop research and development proposal and solicit fundiig support (project team).

5) Hardware and software development and integration (project team).

6) System implementation, evaluation and refinement (project team).

Project Schedule and Cost

It is anticipated that the majority of work associated with the implementation of fourth generation signal control will involve activity integration efforts and software development for data fusion and computer modeling processes. The costs and schedule of this initiative will therefore be largely dependent on earlier program elements. The project potentially could be initiated in the long-term, when an extensive IVHS platform will have been established in the Denver area. As an initial estimate, $400,000 could be applied per year over a three-year period to support development of fourth generation signal control approaches.

Project Funding

Appropriate sources of funding for this project will need to be identified and pursued once its component technologies and functions are defined in more detail. Potential sources include state and local funds, federal IVHS contributions, or input from private sector firms.

Objective #8
Reduce Travel Demand and Enhance Attractiveness of Alternative Modes of Travel

Activities

Interactive Rideshare Management and Matching System

HOV Occupancy Verification

Integrated Demand Management

Smart Cards for Transit Fare Payment

Transit Vehicle Status Monitoring Systems

CDOT/RTD/DRCOG Partnership

INTERACTIVE RIDESHARE MANAGEMENT AND MATCHING SYSTEM

Objective

The key objective of this activity is to improve the convenience of ridesharing. currently, DRCOG manages a rideshare matching system in the Denver area called Ride Arrangers. This program is designed to assist travelers in identifying ridesharers with similar destinations and travel times. Users access the system directly from the home or workplace, obtaining information from an operator or a computer database. This enables travelers to review ridesharing options, identify travelers whose needs most closely match their own, and reserve journeys in advance. At present, however, DRCOG indicates that only about 20 percent of the ride sharers enter the system via call-in The other 80 percent enter the program through outreach efforts by DRCOG. The intent of this activity is to improve the existing Ride Arrangers system through technology. It is not intended to supplant the existing Ride Arrangers system.

This activity will build on the Ride Arrangers program, enhancing it through IVHS application. For example, DRCOG is now developing a GIS-based software program to provide an "insta-match" capability sufficient for general ride-sharing needs. IVHS technology could create a future real-time element of the system permitting ridesharers to enter details for an immediate travel request. Another enhancement could download routing instructions for passenger pickup, reflecting real-time traffic conditions. The database generated by such a system could potentially be integrated into the TOC when sufficiently developed and proven.

Priority

This activity has the potential to make a contribution to congestion relief in the Denver area. Improvements and enhancements to the current interactive rideshare management and matching system will aim to reduce single occupant vehicle use and its associated congestion and environmental impacts. This activity has been included for implementation within the scope of the Early Action Plan, however current enhancements initiated by DRCOG seem to indicate that the current system (with enhancements) will suffice for the short-term.

Applicable IVHS Goals

This activity will primarily address the Denver area IVHS goals which follow:

- Reduce congestion/improve mobility.
- Efficient use of tax dollars.
- Ensure high benefit/cost ratios.
- Contribute to regional air quality goals.

Activity Interrelationship

Currently, DRCOG's Ride Arrangers matching system operates independently. After future enhancements, the database generated by such a system could potentially be integrated into or linked to the TOC when sufficiently developed and proven. This would allow the interactive system to provide real-time traffic data and other relevant information, as well as supporting rideshare matching.

In addition, other potential activities can be approached interdependently with this effort throughout the course of the program. These include:

- TOC database integration.
- HOV occupancy verification.
- Videotex information system.
- Audiotex information systems.

Approach

DRCOG currently manages the existing rideshare matching system in the Denver area. Therefore, they are seen as the appropriate lead agency responsible for overseeing this enhancement effort. It is anticipated that the majority of the work will be software development, performed by private firms under contract to DRCOG. However, some tasks will be undertaken by DRCOG personnel. In addition, CDOT personnel will likely support interfacing the system with TOC equipment.

Scope of Work (SOW)

Implementation of advanced rideshare management and matching will likely be undertaken through a series of incremental enhancements to the current Ride Arrangers system. The following main tasks are representative of the scope of work associated with this effort:

1) Review rideshare matching and management approaches (DRCOG).

2) Prioritize and select enhancement actions for the Ride Arrangers system (DRCOG).

3) Develop procurement documents, request proposals, and select consultant (DRCOG).

4) For each application selected, as directed by DRCOG, the consultant will address the following tasks:

   - Define functionality of the enhancement.
   - Define user interface mechanism.

- Define information output format.
- Prepare design documents and associated materials for enhancement.

5) Review and refine system design (DRCOG/consultant).

6) Software development (consultant).

7) System implementation (DRCOG/consultant).

8) TOC interconnection and enhancement, if needed (CDOT).

Project Schedule and Cost

The project approach presented above has outlined a series of representative tasks that will build upon the existing Ride Arrangers system, advancing interactive rideshare management and matching concepts through to full implementation and operation. It is anticipated that enhancements will be introduced gradually through ongoing software modifications, together with use of alternative communications media such as audiotex and videotex. The level of complexity of each feature and the time at which it is introduced will vary. These variations will then determine the entire system's project schedule and cost.

Due to this activity's variability and incremental implementation approach, a lump sum per annum budgeting approach is recommended. This would set aside $60,000 per year for a four-year period to cover this activity's work scope. As mentioned earlier, the existing system (enhanced) is expected to suffice during the short term, therefore effort could begin in the medium term, building on DRCOG's existing Ride Arrangers program.

Project Funding

DRCOG's lead role in this activity would also entail them to be the partner responsible for seeking funding support. Potential funding sources include federal, state and local funds. If innovative enhancements are pursued, funding sources such as FHWA's IVHS IDEA program may be appropriate. DRCOG could also explore the potential for commercial sponsorship of rideshare management and matching services.

HOV OCCUPANCY VERIFICATION

Objective

This activity aims to increase the person-carrying capacity of the Denver area's existing and planned HOV lane system and to encourage the use of transit, carpools, and vanpools. Key to the success of this program is the investigation of technologies and procedures in which HOV violations can be prevented or detected through lane verification and enforcement strategies. Since frequent violation of HOV priority treatments by non-HOVs can lead to public perception of failure of carpooling programs, care must be taken to implement a comprehensive verification program in which all vehicles will be evaluated.

HOV occupancy verification will take place at selected locations potentially using several different techniques. The component technologies for HOV verification are at different stages of development, with candidates including infrared and ultrasonic sensors, video image processing and CCTV monitoring. Although automated occupancy monitoring has not yet reached a precision level for enforcement requirements, this will likely change through future technology advances. The most promising approaches will be considered for implementation in the Denver area.

Priority

HOV occupancy verification is seen as important to the success of the Denver area's integrated demand management. HOV lane systems have the potential to reduce overall travel times and improve air quality in selected corridors. Verification techniques will decrease the number of HOV violations and encourage the use of HOVs by legitimate carpoolers. In turn, this should lead to increased public acceptance of HOV operations.

Applicable IVHS Goals

This activity will primarily address the following Denver area IVHS goals:

- Integrate existing operations and IVHS activities.
- Provide operational improvements through technology.
- Influence travelers' decision making.
- Reduce congestion/improve mobility.
- Contribute to regional air quality goals.

Activity Interrelationships

Two types of activity interrelationships exist for HOV occupancy verification: integration with existing HOV facilities, and coordination with planned IVHS activities. Currently, four HOV facilities are in operation or undergoing implementation in the metro area:

- Broadway/Lincoln one-way pair bus-only lanes.

- Santa Fe Drive carpool lanes.
- U.S. 36 bus-only lane.
- North I-25 two-lane reversible bus/HOV facility.

These facilities should be considered as potential demonstration corridors for implementation of selected HOV occupancy verification technologies and techniques. Also, the HOV bypass locations at ramp meters may be appropriate as specific locations to test this activity. Initial evaluation activities could use CCTV or other technology at selected locations to determine the extent of violations and determine response needs and requirements. The possibility exists for the Denver TOC to become the verification hub for the metro area's HOV lane system. The North I-25 HOV facility is already scheduled for integration with the TOC and successful coordination could pave the way for further HOV expansion. In addition, the following activities are interrelated with the implementation of HOV occupancy verification:

- Expanded CCTV coverage.
- Collection of real-time traffic volume and speed information.
- TOC database integration.
- Dynamic route guidance.
- Integrated demand management.

Approach

DRCOG is seen as the appropriate lead agency for implementation of this activity. DRCOG completed a regional HOV lane system technical report in April, 1990 which recommended a system of HOV facilities on selected metro area freeway corridors. Their understanding of HOV facilities' unique concerns and issues positions them as the logical coordinating entity for regional implementation of this activity. In addition, it is anticipated that CDOT and selected local municipalities will be significantly involved in demonstration projects along roads within their jurisdiction.

Due to the innovative nature of this project, it is seen as an appropriate activity for an FHWA- or FTA-sponsored operational test. This would involve formation of a public-private partnership to undertake the project and evaluate the system. The North I-25 bus/HOV facility could serve as an initial demonstration corridor for preliminary system trials. This corridor will already contain CCTV cameras, a fiber optic communications network and integrated operations with the Denver TOC. HOV occupancy verification technologies and techniques would build on this existing infrastructure to achieve reduced implementation costs. If initial trials are successful, the systems would be applied on other HOV facilities in the metro area.

Scope of Work (SOW)

Implementation of this activity will likely follow a number of field tests at selected locations. The following main tasks outline the scope of work associated with this effort:

1) Identify demonstration corridors for initial implementation efforts (DRCOG).

2) Identify local government agencies and private sector partners for participation in operational test (DRCOG).

3) The project team, through a series of working groups, will define the scope of the operational test, including the following tasks:

- Confirm initial needs to be addressed by the system as well as the extent of HOV violations.
- Determine functional and performance requirements for the system.
- Review available technologies (e.g., CCTV, AVI, video image processing, infrared and ultrasonic sensors, etc.) applicable to the system.
- Identify most promising approaches for HOV occupancy verification.
- Identify hardware and software development needs.
- Define scope of operational test implementation and nature of the evaluation

4) Develop operational test proposal and solicit federal funding support (project team).

5) Hardware and software development and integration (private sector partners).

6) System implementation and operational evaluation (project team).

If the operational test proves a success, the HOV occupancy verification system will be expanded to additional facilities throughout the metro area. Implementation responsibilities would then fall upon the agencies having jurisdiction over the affected roadways. CDOT would likely be responsible for installing any equipment required at the Denver TOC while DRCOG would support the overall coordination of the deployment effort.

Project Schedule and Cost

The project approach presented above has outlined a series of tasks that will advance this activity through to readiness for full implementation. These can be grouped into four main areas with corresponding schedule and cost estimates, as follows:

	Duration	cost
1) Project team formation (SOW Tasks l-2)	3 months	$25,000
2) System definition and proposal preparation (SOW Tasks 3-4)	6 months	$150,000
3) System development and integration (SOW Task 5)	9 months	$400,000
4) Implementation and operational evaluation (SOW Task 6)	9 months	$500,000
	TOTAL: 27 months	$1,075,000

It is anticipated that this activity's initial efforts could get underway in the medium term, recognizing that the actual start date will reflect technical advancements in the next few years, as well as the actual opening date of the North I-25 bus/HOV lanes in late 1994 or early 1995. If the North I-25 bus/HOV facility is selected as a demonstration corridor, implementation costs may be decreased by utilization of the existing infrastructure.

Project Funding

As discussed previously, this project is expected to be appropriate for consideration as a federally-supported operational test. At this time, IVHS America's IVHS program recommendations include significant dollars per year for HOV lane sensor technologies. However, allocation of federal funding to this project would likely require at least a 20 percent local hard match. As project coordinator, DRCOG would be responsible for securing the necessary funding commitments from CDOT, participating local agencies and involved private sector firms.

INTEGRATED DEMAND MANAGEMENT

Objective

This activity will focus on the integration of conventional demand management approaches with strategies facilitated by IVHS technologies. The principal objective will be to enhance mobiity by preventing capacity overload through a combination of new technologies with proven management techniques. Conventional methods such as rideshare matching systems, HOV lanes and transit will be coupled with IVHS approaches such as AVI systems for toll collection, enforcement systems for restricted areas and technologies that promote transit or HOV use.

Priority

This activity is the coordinating entity for integration of conventional and IVHS-based demand management approaches applied in the Denver metro area. Therefore, implementation of this activity is seen as highly important to support the optimal, multi-modal management of the overall highway transportation system. Coordination of the Denver area's conventional demand management techniques should occur in the short-term. Inclusion of IVHS technologies, and their integration with their more traditional counterparts, should be considered for the medium- term.

Applicable IVHS Goals

This activity primarily addresses the following Denver IVHS goals:

- Reduce congestion/improve mobility.
- Integrate existing operations and IVHS activities.
- Provide operational improvements through technology.
- Influence travelers' decision making.
- Support/enhance transit.

Activity Interrelationships

This activity will have a long-term interdependency with the TOC's operations. TOC resources such as its databases, communications network, and monitoring facilities will be used to coordinate the IVHS-based demand management strategies. Other activities that will provide significant input to the integrated demand management effort include:

- Expanded freeway ramp metering.
- TOC database integration.
- Interactive rideshare management and matching systems.

- HOV occupancy verification.
- Continued evolvement of the CDOT/RTD/DRCOG partnership.

Approach

DRCOG is seen as the logical candidate to lead this effort. DRCOG currently operates Ride Arrangers, a commuter assistance program which supports carpools and vanpools. This program, along with DRCOG's lead role in Denver's HGV lane system and established role as an intejurisdictional facilitator, will allow successful coordination of the metro area's various demand management strategies, and their integration into the Denver area TOC.

In the short-term timeframe, most of the demand management strategies deployed in Denver will be conventional (pre-IVHS) approaches. These will be pursued by DRCOG, working with CDOT and metro area cities and counties.

As this activity moves into the medium-term timeframe, it is anticipated that some IVHS approaches will be sufficiently developed and proven for use in the Denver area. IVHS technologies such as AVI systems and HOV lane sensor technologies will increase the need for involvement by CDOT and the private sector for implementation. CDOT will work with DRCOG to integrate demand management activities at the TOC as well as with the private sector to develop the appropriate IVHS technologies.

Throughout this activity, RTD will be involved to coordinate aspects of demand management relating to transit. RTD's provision of real-time transit information to the TOC and employer incentive arrangements highlight the value of the organization's participation in this effort

Scope of Work (SOW)

As seen from the above program approach, the initial phase of this activity's efforts will focus on the coordination and integration of existing demand management programs, including interconnection into the Denver area TOC. Further activities will concentrate on the implementation of the appropriate IVHS systems and technologies. The following main tasks of this phased approach are outlined below.

Short-term:

1) Review existing demand management approaches and further conventional opportunities in the Denver area (DRCOG).

2) Assess the scope for integration of demand management with the Denver area TOC (DRCOG/Systems Engineer).

3) Assess the scope for integration of demand management with transit (DRCOG/RTD).

4) Implementation of demand management enhancements, including lii to RTD and the TOC (CDOT/DRCOG/RTD).

Medium-term:

5) Review available systems, technologies and previous experience with IVHS in demand management (DRCOG/CDOT).

6) Define principal requirements for operation of integrated demand management (DRCOG/CDOT).

7) Develop procurement documents, request proposals, and select consultant (DRCOG/ CDOT).

8) Integrated demand management systems design (consultant).

9) Hardware supply and software development for selected systems (consultant/CDOT).

10) System implementation and operational evaluation (consultant/CDOT/DRCOG).

Project Scheduling and Cost

This activity will involve coordination of current demand management efforts and integration of new IVHS-based techniques. The activity is expected to be an ongoing effort over the short- and medium-term timeframes. For both of these time periods, a lump sum budgeting approach is recommended, rather than an allocation of funds to specific tasks. The figures outlined below are representative of the funding levels needed to support this effort.

Initial activities will focus on traditional demand management approaches. Funding of $250,000 per year through the short-term is considered appropriate for these efforts.

Subsequent activities will introduce IVHS solutions to the demand management arena, necessitating some new equipment deployment and integration. Funding for the medium-term is therefore increased to $400,000 per year.

Project Funding

The 1991 ISTEA authorizes significant expenditure of federal funds for congestion management and air quality improvement efforts. Demand management is fully consistent with these goals. Therefore, DRCOG should view these ISTEA federal funds as a prime source of support in pursuing this initiative.

SMART CARDS FOR TRANSIT FARE PAYMENT

Objective

This activity involves the design, deployment and evaluation of a smart card system for transit fare payment on RTD's transit vehicles and MAC line. Smart cards will allow regular passengers to use transit services without having to pay cash or purchase travel permits. This will enhance convenience for transit users, reduce delays associated with the fare collection process, and offer increased financial control for RTD. RTD should benefit from this activity not only by providing more timely service to its passengers, but also by using data from the smart cards to assess demand and ridership trends, and thus maintain the optimum number of transit vehicles.

Priority

Implementation of this activity is seen as an important component for the overall success of the multi-modal aspect of the Denver area IVHS Master Plan. By improving the convenience of transit fare payment, smart cards have the potential to enhance the appeal of this mode and thus increase ridership. Although a fairly recent innovation, smart card systems are currently being tested in IVHS initiatives throughout the U.S. and elsewhere in the world. It is expected that this technology will be thoroughly evaluated and available for commercial deployment by RTD in the medium-term timeframe.

Applicable IVHS Goals

The use of smart cards for fare payment has the potential to influence travelers' decision making by offering a more convenient transit service. Other IVHS goals that will be addressed by this activity are as follows:

- Reduce congestion/improve mobility.
- Support/enhance transit.
- Provide operational improvements through technology.

Activity Interrelationships

The initial focus of this activity is to develop a smart card system for RTD. This can be undertaken in conjunction with the following:

- Transit vehicle status monitoring.
- Continued evolvement of the CDOT/RTD/DRCOG partnership.

In the longer term, the successful implementation of this activity within RTD's transit fleet and MAC line could set the foundation for a Denver area smart card. This metro smart card could be used in a number of other applications, potentially including

automatic toll collection and storage for dynamic route guidance instructions. Initiatives along these lines would need the support of CDOT, DRCOG and other local agencies. The continuing CDOT/RTD/DRCOG partnership should provide a forum to pursue such opportunities.

Approach

RTD will be the responsible lead agency for this project. In evaluating the component technologies requited for the smart card activity, RTD will need to assess a large number of vendors' products and prepare a program approach which is not vendor-specific. RTD should identify its primary objectives and requirements from the smart card system, prior to commissioning a system design by a consultant. Equipment supply and implementation will be undertaken by a contractor. In addition, private sector support may be required to assist RTD's marketing and distribution efforts for the new smart card system within the Denver area.

Scope of Work (SOW)

The main tasks representative of the scope of work associated with this activity are outlined below:

1) Identify potential components for RTD smart card system (RTD).

2) Develop procurement documents, request proposals, and select consultant (RTD).

3) Once selected, the consultant, with RTD, will address the following tasks:

   - Review available technologies (e.g., magnetic strip, bar coding, computer chip, etc.) and previous experience with smart card systems.
   - Determine optimal approach for the RTD smart card system. This will include consideration of fare structures, prepayment versus postpayment fate collection methods and identification of potential system users.
   - Determine functional and performance requirements for system hardware and associated software.
   - Prepare design documents and specifications for the RTD smart card system.

4) Develop bid documents, request proposals, and select equipment supplier (RTD/consultant).

5) System deployment within selected RTD transit vehicles (RTD/supplier).

6) RTD smart card distribution to selected transit users (RTD/consultant/supplier).

7) Evaluate trial deployment and refine system design and operational procedures, as required (RTD/consultant/supplier).

8) Fleetwide deployment (RTD/supplier).

Following fleetwide deployment, RTD will need to engage in marketing and promotional activities to support use of smart cards. If the RTD smart card implementation proves the system a success and initial public acceptance is favorable, it may be expanded to additional applications in the Denver metro area. This would likely build on other IVHS program components, using the smart cards for personal data storage and service payment transactions.

Project Schedule and Cost

The project approach presented above has outlined a series of tasks that will advance this activity through to full system implementation. Corresponding schedule and cost estimates for the effort are as follows:

	Duration	Cost
1) RTD preparatory work (SOW Tasks l-2)	3 months	$30,000
2) System design and equipment supplier selection (SOW Tasks 3-4)	9 months	$150,000
3) Trial deployment and evaluation (SOW Tasks 5-7)	6 months	$400,000
4) Fleetwide implementation (SOW Task 7)	6 months	$1,800,000
TOTAL:	24 months	$2,380,000

It is anticipated that RTD's smart card initiative will get underway during the medium-term.

Project Funding

It is anticipated that RTD will be responsible for allocating funding to this smart card project. Potential funding sources include FTA grants and local taxes used to support RTD's operations.

TRANSIT VEHICLE STATUS MONITORING

Objective

This activity aims to apply in-vehicle sensors to monitor RTD's transit fleet's vehicle status in real-time for operational and maintenance purposes. To achieve this objective, the activity will essentially be divided into two phases. The first phase will investigate the in-vehicle equipment needed to operate real-time vehicle status monitoring. In addition, this phase of the study will address the use of in-vehicle systems for monitoring passenger loading. The second phase of the project will integrate these technologies with RTD's GPS-based communications system. This real-time information will allow RTD's dispatch centers to optimize service and maintenance schedules so as to maximize utility and minimize the time vehicles are off the road.

Priority

This activity will contribute to the APTS component of IVHS in the Denver area, with the overall goal of increased transit ridership and decreased congestion on the metro area's roadway network Specifically, this activity will aim to use advanced technologies to gather real-time transit vehicle status information. This monitoring capability will enable RTD to use its resources more efficiently, thus decreasing costs, while simultaneously improving service reliability for transit users.

It is worth noting that RTD has previously explored the use of transit vehicle status monitoring systems, and found them to be unreliable. However, this project is not scheduled for implementation until the medium-term timeframe of the IVHS program. By this time, it is anticipated that technical advances will have resulted in satisfactory levels of performance.

Applicable IVHS Goals

This activity will primarily address the Denver IVHS program goals which follow:

- Reduce congestion/improve mobility.
- Provide operational improvements through technology.
- Support/enhance transit.
- Provide opportunities for private sector participation.

Activity Interrelationships

This activity will build upon the foundation established by the continuing CDOT/RTD/DRCOG partnership to develop common goals and procedures. Close coordination, and perhaps even integration, with CDOT's maintenance fleet management system and this activity could be undertaken. Communication links between the Denver area TOC and

the RTD operations center will highlight the information exchange between each agency's vehicle fleet.

Additional activities that are related to this effort include:

- Audiotex information systems.
- Smart cards for transit fare payment.

Approach

Since this activity focuses its efforts on the Denver area's transit vehicle fleets, RTD is the logical choice to lead the initiative. However, a coordinated RTD/CDOT effort could be developed if integration of both agencies' vehicle fleets is desired. It is anticipated that the work will follow a traditional approach, in which the system design will be prepared by a consultant, and implementation will be undertaken by a contractor.

Scope of Work

The scope of work associated with this project will develop a system design to be deployed in a limited number of RTD's transit vehicles for evaluation, prior to fleetwide implementation as appropriate. Specific tasks for this activity include the following:

1) Define goals of the transit monitoring system and desired functions (RTD).

2) Develop procurement documents, request proposals, and select consultant (RTD).

3) Review available technologies (e.g., brake wear sensors, engine speed sensors, fuel consumption gauges, etc.), performance levels and previous experiences with vehicle status monitoring systems (consultant).

4) Determine RTD's optimal approach and undertake system design (consultant).

5) Prepare system specifications and request proposals for system supply and integration (RTD/consultant).

6) Hardware and software development for the transit vehicle status monitoring system (supplier).

7) Deploy trial in-vehicle sensor equipment and system software for evaluation (supplier).

8) Integrate transit vehicle status monitoring system with RTD's GPS-based communications system (RTD/supplier).

9) Evaluate trial deployment and refine system design as required (RTD/supplier).

10) Fleetwide system deployment (supplier).

In the approach above, it is anticipated that the vehicle status monitoring system design, development and operational evaluation will be for RTD's transit fleet only. However, CDOT may choose to involve itself within this initiative for increased cost-efficiency through integration with its maintenance fleet management system. If this occurs, CDOT could complement RTD's lead role in the scope of work defined above.

Project Schedule and Cost

The series of tasks outlined above present a project approach which will design, develop, test and deploy a transit vehicle status monitoring system for RTD. Corresponding schedule and cost estimates are as follows:

	Duration	cost
1) RTD preparatory work (SOW Tasks l-2)	3 months	$30,000
2) Technology review and system design (SOW Tasks 34)	6 months	$150,000
3) Supplier selection, limited implementation and evaluation (SOW Tasks 5-9)	9 months	$500,000
4) Fleetwide deployment (SOW Task 10)	6 months	$1,200,000
	TOTAL: 24 months	$1880,000

It is anticipated that this activity's efforts will get underway late in the medium-term. By this time, some vehicle status monitoring equipment should be proven and commercially available and RTD's GPS-based communications system should be fully operational.

Project Funding

RTD will be responsible for seeking funding support for this activity. Federal IVHS funding for electronic safety inspection systems is currently available. In addition, since this activity focuses on transit enhancement, it may also qualify for congestion mitigation and air qualify funding support set aside under ISTEA.

CDOT/RTD/DRCOG PARTNERSHIP

Objective

This activity will focus on continuing the on-going relationship between CDOT, RTD, and DRCOG, as well as other agencies in the Denver area throughout the planning period. Building on long-standing relationships and CIMC coordiation efforts begun in 1992, this partnership would establish a permanent CDOT/RTD/DRCOG liaison committee. This committee would meet quarterly or as required to discuss topics of interest between the agencies. Matters of discussion could include:

- Advances in APTS technologies and methods of incorporating these into the Denver Regional Transportation System.
- Incident management.
- Traffic signal coordination issues.
- Demand management.
- Information sharing.
- Funding issues, through DRCOG' s position as Metropolitan Planning Organization (MPO).
- Expansion of the MAC line along the State Highway system.
- Data and communication ties between the RTD GPS system and the TOC. Once these ties are established, there is a potential (through the AVL capabilities of RTD's system) to *use* express buses as probes to help determine freeway speeds.
- Intermodal facilities beyond the one proposed at the I-7O/Morrison interchange location. These intermodal facilities could incorporate bus, train, van, automobile, bicycle, and pedestrian traffic.

The committee should be maintained through the long-term as it will not only provide a forum for discussion but would provide a sound basis for the establishment of more interagency partnerships in the future. Others could be involved on a periodic or permanent basis.

Priority

The continuation of this coordination activity is important to support the reduction of traffic demand and enhance alternative modes of travel in the Denver area NHS Program. Under the guidelines of ISTEA, regions such as the Denver area which are shown to be in noncompliance with air quality provisions must be willing to evaluate alternative modes

of transportation. The bus service and soon-to-be-implemented light rail branches of RTD will comprise the majority of alternative modes available in the short- to medium-term. Therefore, a close working relationship between CDOT and RTD will continue to prove highly beneficial. DRCOG's role as the MPO and their continuing work on regional planning and traffic signal issues make them an important third participant. Due to the overall importance of this activity, it has been included for "implementation" within the scope of the Early Action Plan, although the relationship already exists and likely will extend into the long-term timeframe.

Applicable IVHS Goals

This activity will primarily address the Denver area IVHS goals which follow:

- Reduce congestion/improve mobility.
- Support/enhance transit.
- Ensure efficient use of tax dollars.
- Contribute to regional air quality goals.

Activity Interrelationships

The establishment of the Denver area TOC is important to this activity since it will provide data and communication ties between RTD and CDOT. This source of information sharing will enhance the multi-modal aspects of IVHS in the Denver metro area.

In addition, other potential initiatives can be undertaken in conjunction with this coordination activity. These include:

- TOC database integration.
- Maintenance fleet management systems.
- Audiotex information systems.
- Transit vehicle status monitoring.

Approach

This coordination activity will focus on continuing the permanent relationship between CDOT, RTD, and DRCOG. This partnership will entail the agencies to be co-leaders responsible for undertaking this effort. It is anticipated that the majority of the work will be performed by personnel of the respective agencies. Some consultant input may be required to support the work of the CDOT/RTD/DRCOG liaison committee.

Scope of Work (SOW)

This is really a coordinating activity, rather than a technical effort. Therefore, it does not have a scope of work in the normal sense. However, the partnership is already established and will maintain this close relationship throughout the planning period. Potential activities of this partnership committee and associated consultant support are outlined below:

1) Exchange data and discuss related issues.

2) Identify potential partnership projects.

3) Prioritize and select partnership projects.

4) Develop procurement documents and select consultants.

5) Oversee and manage partnership-supported projects.

As outlined above, CDOT, RTD, and DRCOG will be the primary organizations responsible for overseeing implementation of any combined projects within the Denver area, using guidance provided by the consultant. In undertaking this work, the liaison committee should examine the potential for public-private partnerships in the deployment of these joint projects.

The liaison committee should also address opportunities to enhance existing programs. For example, CDOT is already cooperating with RTD in the construction of a two-lane reversible bus/HOV facility in the North I-25 Corridor between 70th Avenue and 20th Street. When completed, the bus/HOV facility will include a state-of-the-art traffic management system with an extensive network of loop detectors, CCTV monitoring, variable message signs, and computer-aided command and control capabilities. CDOT will be responsible for the control and operation of this system, the capabilities of which are limited to the bus/HOV lanes and do not include the I-25 general traffic lanes. RTD will have the system monitoring functions tied into its dispatch center. Construction of the bus/HOV lanes will encourage the use of transit and ridesharing programs and relieve congestion on North I-25.

RTD is also currently working to implement a GPS-based AVL and computer-aided dispatch system for its bus fleet. Current communications capabilities will be greatly enhanced, through implementation of the GPS. RTD will use the system to monitor the existing bus fleet, as well as trains when the Metro Area Connection (MAC) light rail system becomes operational. There exists the potential for data and communication ties between the RTD GPS system and the Denver area TOC. Once these ties are established, opportunities for increased cost-efficiency through integration with CDOT and the CSP should be considered in this area.

CDOT, RTD, and DRCOG are currently working together in the CIMC as well as continuing ongoing signal coordination work. DRCOG and RTD frequently interact to

promote alternative modes of travel. A continued partnership between the three agencies would provide opportunities to discuss and prioritize potential projects and to discuss funding issues.

Project Schedule and Cost

The discussion presented above has outlined potential activities that will advance joint projects through to full implementation and operation. However, as discussed previously, these will be primarily coordinating roles, rather than technical efforts. Any technical support will likely be provided through a consultant to the CDOT/RTD/DRCOG liaison committee.

Therefore, due to this activity's variability, a lump sum per annum budgeting approach is recommended. It is proposed that CDOT, RTD, and DRCOG set aside $100,000 per year to cover required consultant support and other costs. This could begin in the late short-term when the TOC is commissioned and the North I-25 Corridor project is completed. Before this time, it is considered unlikely that there would be sufficient technical activities to necessitate hiring a consultant.

Project Funding

The joint lead roles of CDOT, RTD, and DRCOG in this activity will also entail them to be the partners responsible for seeking funding support for projects worthy of pursuit. Funding sources for this activity include federal funds and state funds. If other agencies such cities or counties, wish to be involved on a periodic or permanent basis, they may also be considered as potential funding sources.

In considering partnership opportunities, the liaison committee should also seek to identify opportunities for public-private partnerships in this area. This may lead to partial funding support through private sector in-kind contributions.

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